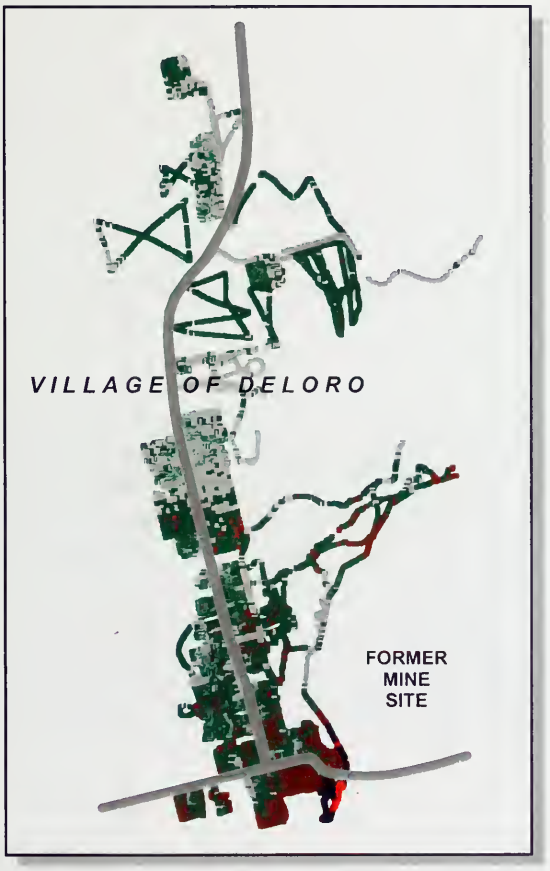
PIBS 3794 e03

Results of Environmental Radiation Monitoring Conducted in Support of the Deloro Village Environmental Health Risk Assessment

July 1999



Prepared for:

Ontario Ministry of the Environment

Prepared by:

SENES Consultants Limited

Cover: Figure illustrating the results of a large area gamma radiation survey of the Village of Deloro.

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30 July 1999

32472

Ms. Lisa Mendonça
CH2M Gore & Storrie
180 King St. S.
Waterloo, Ontario
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Re: Final Radiation Monitoring Report - Deloro, Ontario

Dear Lisa:

Enclosed is the final report on the findings of the environmental radiation investigations conducted by SENES Consultants within the Village of Deloro. The investigations involved measurements of outdoor gamma radiation levels and indoor and outdoor radon gas concentrations on participating properties. The information collected as part of this investigation was used to support the radiological exposure assessment component of the environmental health risk study for the Village. Appendix F contains a CD of the raw field data and only one copy of this CD has been produced for the Ministry of the Environment files.

If you have any questions about the report, please contact either Dr. Leo Lowe in Richmond Hill at (905) 764-9380 or the undersigned in Port Hope at (905) 885-9360.

Yours very truly,

SENES Consultants Limited

G. Glenn Case, P.Eng.,
Associate,
Manager Port Hope Office

Report on

The Results of Environmental Radiation Monitoring Conducted In Support of the Deloro Village Environmental Health Risk Assessment

Prepared For the

Ontario Ministry of the Environment

By

SENES Consultants Limited
128 Walton Street
Port Hope, Ontario
L1A 1N5

July 1999

EXECUTIVE SUMMARY

In the fall of 1998, a health risk assessment was initiated to estimate the level of risk to residents within the Village of Deloro attributable to potential exposures to arsenic, other metals and radionuclides resulting from their proximity to the former mine site. To provide site-specific data for the risk assessment, SENES Consultants Limited, with the assistance of the Low-Level Radioactive Waste Management Office, conducted radiation monitoring within the Village of Deloro. The types of sampling and analysis were as follows:

- Outdoor Gamma Radiation measurements on participating private properties within the Village of Deloro;
- Indoor Radon Gas measurements in participating private residences within the Village of Deloro; and,
- Outdoor Radon Gas measurements at 11 locations selected by the project management team.

There are approximately 77 residential dwellings within the study area and participation in the radiation monitoring program was voluntary.

Indoor Radon Gas

Indoor radon gas concentrations were measured in 57 participating homes within the Village using passive E-PERM electret radon monitors. The E-PERMs were placed in pairs (i.e. replicate samples) at designated locations in each home. One pair of monitors was placed within the main floor living area where residents spend much of their time, while the other pair of monitors was either deployed in the basement area (where the radon in air concentrations are expected to be highest), or if there was no basement, in an upper floor area.

The monitors remained in place for approximately two weeks. The deployments occurred during 19 to 21 October 1998 and retrievals were performed during 2 to 3 November 1998. At the time of detector deployment, a field data sheet was completed (e.g. E-PERM serial numbers, date, time and gamma radiation level at the place of deployment) along with a dwelling data sheet summarizing physical details about the structure (i.e. approximate age, number of storeys, heating system, type of basement foundation, type of basement floor, etc.).

Table 1 presents a statistical summary of the radon concentration data collected within the 57 homes. The average concentration for a Deloro Village home main floor is 56 Bq/m^3, while the

average for a basement area is 101 Bq/m^3. The maximum concentration measured in the 57 homes on the main floor was 284 Bq/m^3, while the maximum in a basement area was 392 Bq/m^3.

Table 1
Overview of Radon Concentrations For Deloro Village Homes
Sampled During October 1998

Area of Home	Mean Conc. (Bq/m^3)	Maximum Conc.(Bq/m^3)	Minimum Conc.(Bq/m^3)	Number of Samples
2nd Floor	30	51	8	8
Main Floor	56	284	11	120
Basement	101	392	17	94

Based on a review of the radon gas data, the living areas in 10 residences and the Deloro Pumphouse have or may be close to having radon and corresponding radon daughter concentrations in excess of the April 1977 Federal Provincial Task Force Criterion for radon of approximately 150 Bq/m^3, corresponding to a radon progeny level of 0.02 Working Levels. The 1977 criterion sets the primary clean-up or remedial action level for radon daughters at 0.02 Working Levels (WL). This criterium is more restrictive than the more recent 1988 radon guideline developed by Health Canada, which recommends that remedial actions be implemented if radon levels in indoor air, as an estimated annual average in a normal living area, are greater than 800 Bq/m^3.

Outdoor Radon Gas

E-PERMs were deployed within protective shelters at the 11 ambient air monitoring stations selected by CG&S (10 sites within the Village and 1 in Marmora, dustfall and suspended particulate samplers had been deployed at most of these locations) for a period of approximately 4 weeks (e.g. 16 October to 13 November 1998).

The results of the ambient outdoor radon monitoring are presented on Table 2. Most stations show radon levels below the effective reporting limit of 10 Bq/m^3. The highest value is 28.9 Bq/m^3 at Station 11 (vacant lot near main entrance to the former mine site). Outdoor radon levels were typically around or below the effective reporting limit.

Table 2
Results of Ambient Radon Monitoring

Station Number, ID Number and General Location	Maximum (Bq/m^3)	Avg. Conc. (Bq/m^3)
#1 [l]- north of main gate	< 10	< 10
#2 [g]- central Village east	< 10	< 10
#3 [v]- central Village east	< 10	< 10
#4 [z]- central Village west	< 10	< 10
#5 [ak]- central Village west	< 10	< 10
#6 [bb]- northern Village east	< 10	< 10
#7 [bp]- north of Village	< 10	< 10
#8 [bw]- north of Village	< 10	< 10
#9 [b]- north of Village	< 10	< 10
#10 [a]- Marmora Twsp Office	< 10	< 10
#11[da]- south of main gate	28.9	22.1

There are no criteria for outdoor radon. The highest outdoor radon concentration (28.9 Bq/m^3) was measured on the vacant lot near the main entrance to the former mine site. A review of the individual results suggests that the typical ambient outdoor radon concentration for the study area is in the order 10 Bq/m^3 (the effective reporting limit for the study). The levels are typical of Ontario background conditions. The data do not indicate a distinctive trend in concentrations versus distance from the former mine site.

Surface Gamma Radiation

Gamma radiation measurements were taken across the surface of participating private properties using scintillometer radiation detectors (scintillometers are well suited for this type of monitoring because of their reliability and sensitivity to minor variations in background gamma radiation levels). These scintillometers were connected to individual recording and analyzing instruments (e.g. ratemeters, scalers, dataloggers, etc.) designed for specific types of applications required during the course of the Deloro Village investigations. The various radiation monitoring systems used during the 1998 program in Deloro were i) Large Area Gamma Survey [LAGS] System, ii) Roving GPS/Gamma Survey System, and iii) Hand-Held Gamma Survey System.

Gamma radiation surveys using the LAGS cart system were conducted on 63 private occupied residential properties within the study area. In addition to these private residential properties, LAGS surveys were also conducted on i) the Village's park area and baseball field located to the west of O'Brien Road, ii) on the property in the immediate vicinity of the Deloro Pump House, iii) on the yard area to the rear of the Community Hall/Library building, and iv) on the accessible portions of the vacant lot near the main gate to the former mine site.

Roving GPS gamma surveys were conducted i) along the rear laneway east of O'Brien Road, ii) along portions of the rear laneway to the west of O'Brien Road, iii) along the Deloro Dam Roadway, iv) along the series of recreational trails located to the east of the main village, v) along the western perimeter fence line of the former mine site between the northern recreational trail area to the main gate into the site, and iv) in several of the open fields adjacent to the homes in the northern part of the study area.

Over 175,000 gamma radiation measurements were recorded during the course of the October 1998 investigations. Table 3 presents a summary of the data.

Table 3
Overview Statistics For Gamma Radiation Surveys

Site or Area	Mean Gamma (µR/h)	Max Gamma (µR/h)	Min Gamma (µR/h)	Number of Measurements
63 residential sites	6.7	55.5	< 3.0	135,678
Baseball field & Village park	6.8	48.7	2.6	18,614
Community Centre and Library	7.5	15.9	3.0	9,666
Wooded lots near Central Village	6.0	9.0	4.0	464
Deloro Pump House Property	7.4	11.0	< 3.0	1,606
West Mine Site Fenceline	9.7	100.8	4.4	405
Vacant lot near former mine site	47.9	467.7	11.7	1,378
East Laneway behind O'Brien	6.5	9.0	3.9	223
Recreational trails	7.1	54.8	3.0	2,119
Deloro Dam Roadway	4.8	6.7	3.3	135

The 1977 Federal Provincial Task Force also established a primary criterion for gamma radiation outside buildings of 100 μR (microroentgen)/h at a height of 1 metre above the ground. An exceedence of this criterion prompted remedial action to reduce levels to as low as reasonably achievable (ALARA), taking social and economic factors into consideration. This criterion was based on an annual exposure limit of 5 millisievert (mSv). The pending reduction to the public (non-atomic radiation worker) dose limit by the Atomic Energy Control Board (AECB) to 1 mSv per year from the current 5 mSv per year, would reduce this criterion level to 20 μR/h (above background).

A review of the data indicates that the 1977 criterion is exceeded on one property, specifically the vacant lot near the main entrance to the former mine site. One metre above ground height gamma radiation levels on this property exceed the 1977 Task Force criteria along the eastern perimeter of the vacant lot.

Elevated gamma radiation levels are present predominantly in the southeastern corner of the study area, in the vicinity of the main gate to the former mine site. Much of the gamma radiation is attributed to gamma radiation shine from radioactive material located on the former mine site. The range of influence of this material is limited and the gamma radiation levels decrease rapidly with distance and reach background levels within a few hundred metres of the western site boundary.

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1.0 BACKGROUND TO ASSIGNMENT AND SCOPE OF WORK

1.1 OVERVIEW

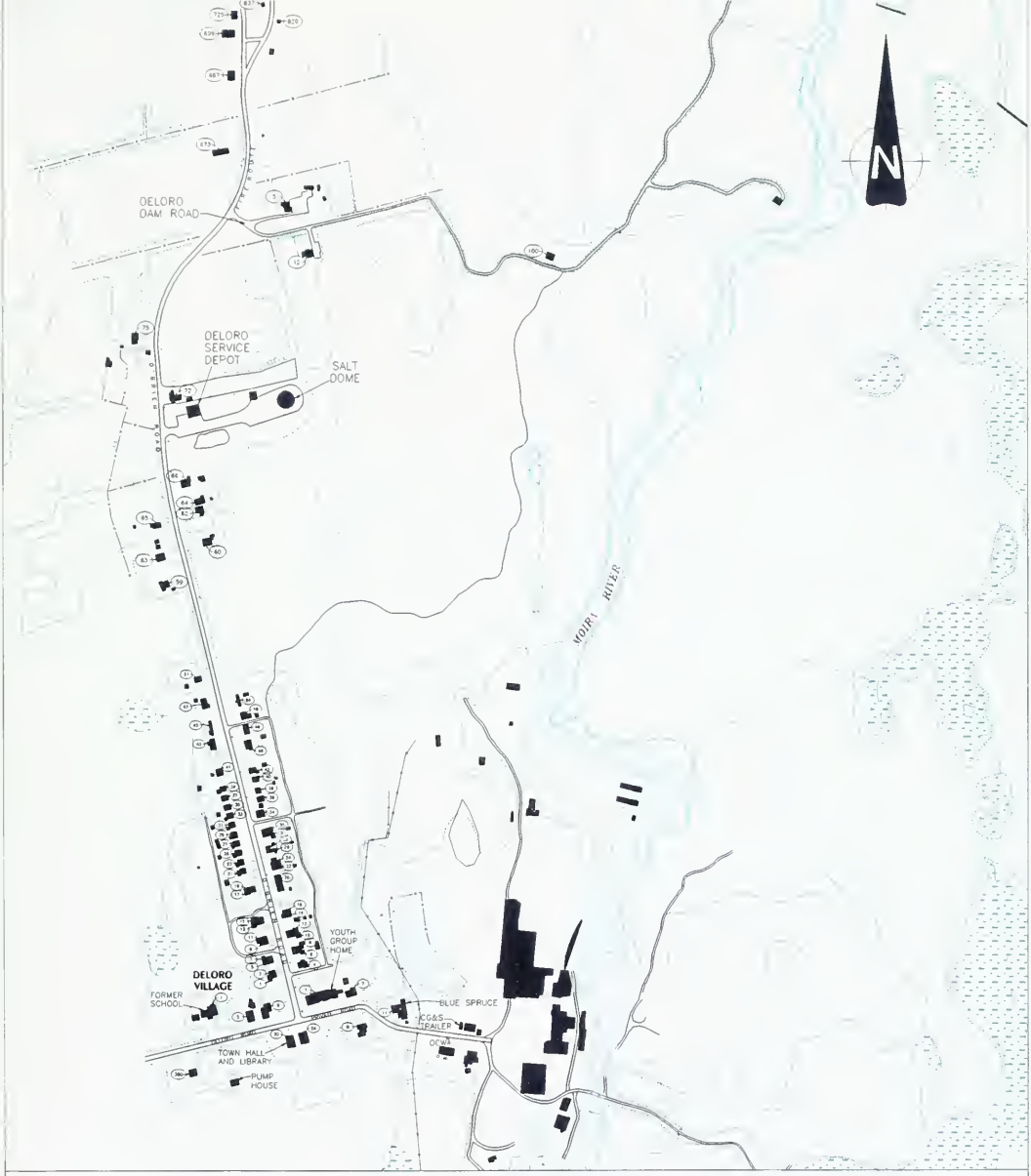
The Ontario Ministry of the Environment (MOE) has contracted CH2M Gore & Storrie (CG&S) to provide overall project management and coordination on its behalf for the Deloro Mine Site Rehabilitation Project. As part of the development of an effective rehabilitation plan for the Deloro mine site, a health risk assessment was initiated in the fall of 1998 to provide information on the magnitude of risk to residents within the Village of Deloro due to their potential exposures to elevated levels of arsenic, other metals and radionuclides resulting from their proximity to the former mine site. The results of the health risk study will also provide guidance in the planning of effective on-site and off-site, if required, remedial actions.

In support of the Deloro Village Environmental Health Risk Assessment component for *Exposure Assessment and Health Risk Characterization For Radionuclides, Gamma Radiation and Radon*, the MOE, through its agent CG&S, contracted SENES Consultants Limited to conduct radiation monitoring within the Village of Deloro. The original radiation monitoring requirements developed by the Project's Technical Steering Committee were set out in the Terms of Reference for the Deloro Village Environmental Health Risk Study under Major Component iii) *Environmental Sampling and Analysis for Radioactivity.* Based on subsequent discussions with members of the consultant team selected by the MOE to implement the Health Risk Study, the requirements for the environmental sampling and analysis for radioactivity component were revised to yield the following scope of the work and tasks:

- perform surface gamma radiation surveys on participating private properties within the Village of Deloro using the Large Area Gamma Survey (LAGS) cart technology developed by Low Level Radioactive Waste Management Office (LLRWMO) in association with SENES Consultants;
- measure indoor radon gas concentrations in participating private residences within the Village of Deloro using E-PERM radon monitoring devices;
- measure outdoor radon gas concentrations at 11 locations selected by CG&S using E-PERM radon monitoring devices; and
- prepare a report that presents the results of the surface gamma and radon monitoring programs

1.2 STUDY AREA AND LEVEL OF PARTICIPATION

Figure 1.1 presents an overview of the study area assigned to the project. Within this area are approximately 77 residential dwellings. Participation in the radiation monitoring program was



BASE MAPPING SUPPLIED BY C G AND S

FIGURE 1.1

STUDY AREA

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voluntary, and on this basis indoor radon concentrations were measured within 57 residences, as well as within the Deloro Pump House and Marmora Township Office, in Marmora, Ontario. Gamma radiation surveys were conducted on 63 participating residential properties. Surveys were also conducted on: the Village park area and baseball field located west of O'Brien Road; the property near the Deloro Pump House; the Community Hall/Library building rear yard; on the accessible portions of the vacant lot near the main gate to the former mine site; along the rear laneway east of O'Brien Road; along the Deloro Dam roadway; along a series of recreational trails located to the east of the main Village; along the western perimeter fenceline of the former mine site; and, in several open fields adjacent to the homes in the northern part of the study area.

Table 1.1 presents a summary of the sites surveyed in October 1998 as part of this radiation monitoring program.

Table 1.1
Summary of Participating Sites in
October 1998 Radiation Monitoring Program

Location ID	Semi or Detached	Indoor Radon Site[1]	Surface Gamma Site[1]
d	D		
e	D	Yes	Yes
f	D	Yes	Yes
g	D	Yes	Yes
h	D	Yes	Yes
b	D	Yes	Yes
c	D	Yes	Yes
br	D	Yes	Yes
bs	D	Yes	Yes
bt	D	Yes	Yes
bu	D	Yes	Yes
bv	D	Yes	Yes
bw	D	Yes	Yes
bx	D		
by	D	Yes	Yes
bz	D	Yes	Yes
i	D		Yes
j	D	Yes	Yes
k	D	Yes	Yes
l	D		Yes

Table 1.1, cont'd.

Summary of Participating Sites in October 1998 Radiation Monitoring Program

Location ID	Semi or Detached	Indoor Radon Site[1]	Surface Gamma Site[1]
n	S		
o	S		
p	D	Yes	Yes
q	S	Yes	Yes
r	S	Yes	Yes
s	S	Yes	Yes
t	S	Yes	
u	S	Yes	Yes
v	S	Yes	Yes
w	S		
x	S	Yes	Yes
y	S	Yes	Yes
ya	S		Yes
z	S	Yes	Yes
aa	S	Yes	Yes
ab	S		Yes
ac	S	Yes	Yes
ad	D		
ae	D	Yes	Yes
af	S	Yes	Yes
ag	D	Yes	Yes
ah	S	Yes	Yes
ai	D	Yes	Yes
aj	S		Yes
ak	D	Yes	Yes
al	S	Yes	Yes
am	D	Yes	Yes
an	S	Yes	Yes
ao	D	Yes	Yes
ap	S	Yes	Yes
aq	D	Yes	Yes

Table 1.1, cont'd.

Summary of Participating Sites in October 1998 Radiation Monitoring Program

Location ID	Semi or Detached	Indoor Radon Site[1]	Surface Gamma Site[1]
ar	D	Yes	Yes
as	D		
at	D	Yes	Yes
au	D	Yes	Yes
av	D	Yes	Yes
aw	D		
ax	D	Yes	Yes
ay	D	Yes	Yes
az	D	Yes	Yes
ba	D		
bb	D	Yes	Yes
bc	D		Yes
bd	D		Yes
be	D		
bf	D	Yes	Yes
bg	D		
bh	D	Yes	Yes
bi	D	Yes	Yes
bj	D	Yes	Yes
bk	D		Yes
bl	D	Yes	Yes
bm	D	Yes	Yes
bn	D	Yes	Yes
bo	D	Yes	Yes
bp	D	Yes	Yes
bq	D		
da	D		Yes
m	D	Yes	Yes
a	D	Yes	

Note:

1 blank entry denotes non-participation in radon monitoring or gamma radiation survey

1.3 OUTLINE OF REPORT

Chapter 1, Overview, provides the background to the investigations, the scope of work involved and the site surveyed within the Village of Deloro.

Chapter 2, Radon Sampling Program, describes the instrumentation used to conduct the radon monitoring at the participating indoor and outdoor sampling locations. The results of the monitoring are also presented.

Chapter 3, Gamma Radiation Survey Program, describes the instrumentation used to conduct the various types of gamma radiation surveys on the participating properties within the Village. The results of the monitoring are also presented.

Chapter 4, Discussion of Results, presents a general discussion of the results and appropriate statistics summaries for use in the radiological component of the health risk study.

Appendix A, Description of Instrumentation and Data, presents a detailed description of the instrumentation and types of data collected during the October 1998 field investigations to characterize levels of radiation exposure in Deloro, Ontario.

Appendix B, Structure and Content of Database, provides an overview of the structure and content of the electronic files created within Microsoft Access to support the compilation of the field data and subsequent presentation and analysis of the data.

Appendix C, Summary of Interior Radon Data, presents a compendium of radon concentrations measured within the residential structures in the Village of Deloro.

Appendix D, Summary of Exterior Gamma Radiation Data, presents a compendium of gamma radiation levels measured on the residential properties within the Village of Deloro.

Appendix E, Response to Comments on Draft Repot, presents a summary of the responses to comments on the draft report provided by the peer reviewers.

Appendix F, Inventory of Raw Field Data, presents (in CD-ROM format) a complete compilation of all the raw field data contained within the Microsoft database program Access. Only one copy of this CD has been produced for the Ministry of Environment.

1.4 ACKNOWLEDGEMENTS

SENES Consultants Limited gratefully acknowledges the assistance provided by the Low-Level Radioactive Waste Management Office in the supply and analysis of E-PERM radon monitors and technical assistance in the application of the Large Area Gamma Survey system.

2.0 RADON SAMPLING PROGRAM

2.1 GENERAL

Radon is a naturally occurring odourless, colourless radioactive gas created by the natural radioactive decay of uranium and thorium, and by the decay of their daughter products (i.e. specifically the radioactive intermediate radium). Since uranium and radium are present all over the earth, radon (an intermediate decay product) is also present everywhere. In outdoor conditions, radon that is released from the soil disperses rapidly in the air and, as a result, radon concentrations remain very low. For indoor conditions, radon can build-up within a structure and can result in concentrations that are generally higher in buildings than outdoors.

Radon can be found in high concentrations where soils and rock contain above background levels of uranium, granite, shale or phosphate. Radon can also be found in soils affected by certain types of industrial waste and residues, such as those from uranium and phosphate mining and refining operations. Historical operations at the Deloro mine site involved the reprocessing of uranium and radium residues for the recovery of cobalt and other metals. The slag-type wastes from these recovery operations contain above background levels of uranium and radium and can be found on the former mine site.

The purpose of the radon sampling program was to support the radiological health risk study by determining the range of typical radon concentrations in Deloro Village homes. Based on the naturally occurring granite bedrock in the area, and the presence of historical radioactive wastes on the mine site, above background radon gas concentrations could potentially exist due to either natural or man-made conditions. No attempt was made as part of this monitoring program to differentiate as to the potential underlying source of the radon gas.

Radon gas concentrations were measured inside 57 participating homes within the Village and at 11 ambient outdoor sites (i.e. 10 sites within the Village and 1 in Marmora). The instrumentation to conduct these measurements and the results of the testing are presented in the following sections. Appendix A presents a detailed description of the instrumentation used for the monitoring and types of data collected during the October 1998 field investigations.

2.2 INSTRUMENTATION

The measurement of radon concentrations in air were conducted using passive E-PERM electret radon monitors. E-PERM monitors are small, unobtrusive devices that do not require power and can be easily placed almost anywhere in a home or inside small protective shelters in an outdoor

setting. These devices measure the ionization in a volume of air, and are sensitive to both ambient gamma radiation and radon decay products in the E-PERM chamber. To address their sensitivity to gamma radiation, gamma radiation measurements are taken at the time of deployment and retrieval to document ambient gamma radiation levels within the area of the E-PERM monitor. These gamma measurements are subsequently used in the calculations to correct the E-PERM readings to reflect only the radon in air concentration.

The E-PERM electret radon monitors used in the study were 200 ml "S type" chambers fitted with ST electrets. The monitors were supplied and analyzed by the Low-Level Radioactive Waste Management Office (LLRWMO) Port Hope Field Service Office. The radon concentrations were calculated as per the method provided in the Rad Elec E-PERM Manual.

2.3 INDOOR RADON

2.3.1 SAMPLING PROGRAM AND LOCATIONS

The measurement of indoor radon concentrations in air within each participating home was conducted using passive E-PERM electret radon monitors. The E-PERMs were placed in pairs (i.e. replicate samples) at designated locations in each home. One pair of electrets was placed at a location selected by the field team within the main floor living area where residents spend much of their time, while the other pair of monitors was either deployed in the basement of the home where the radon in air concentrations are expected to be highest, or if there was no basement, in an upper floor above the main floor. For instances of a single story home without a basement, only one pair of E-PERM monitors was deployed in the structure.

Paired E-PERM monitors are useful for screening out anomalous readings, which occur with a frequency of approximately 5%. With paired measurements, the probability of not having at least one good measurement decreases to approximately one in four hundred. There were 57 homes tested in this survey and valid data were collected for every participating home without the need for followup measurements.

The monitors remained in place for approximately two weeks. The deployments occurred during the period of 19 to 21 October 1998 and retrievals were performed during the period of 2 to 3 November 1998. During this sampling period, windows in the homes were generally closed and the heating systems were not yet in full use due to the mild fall temperatures. As a result, the radon gas concentrations measured during this period could represent maximum potential values for the specific occupancy conditions of the home (e.g. number of adults and children, frequency of door openings, etc.).

At the time of detector deployment, a standardized field data sheet was completed to record the specific E-PERM serial numbers, date, time and gamma radiation level at the place of deployment. Figure 2.1 presents an example of this form. In addition to the field data form, a standardized dwelling data sheet was completed that summarized physical details about the structure (i.e. approximate age, number of storeys, heating system, type of basement foundation, type of basement floor, etc.). Figure 2.2 presents an example of the dwelling data form that was completed for each home. Data recorded on both forms were subsequently entered into the Microsoft Access database for the project. Appendix B provides an overview of the structure and content of the electronic files created within Microsoft Access to support the compilation of the field data and subsequent presentation and analysis of the data.

Figure 2.1: FIELD DATA SHEET FOR INTERIOR RADON SAMPLING

Dwelling ID: _____

INSTALLATION:

Date: _____ 1998 Time:_____

Basement

Gamma Radiation: _____μR/h, Inst.#: _____

E-Perm Serial Numbers: _____, _____

Location Description :_____

Comments _____

Main Floor

Gamma Radiation: _____μR/h, Inst.#: _____

E-Perm Serial Numbers: _____, _____

Field Technician: _____, _____

Location Description :_____

Comments _____

REMOVAL:

Date: _____ 1998 Time:_____

Basement

Gamma Radiation: _____μR/h, Inst.#: _____

E-Perm Serial Numbers: _____, _____

Main Floor

Gamma Radiation: _____μR/h, Inst.#: _____

E-Perm Serial Numbers: _____, _____

Field Technician: _____, _____

Comments _____

Figure 2.2 : DWELLING DATA SHEET FOR INTERIOR RADON STATIONS

Station ID: _____ _____

Date: _____ 1998

Structure Conditions:

Approximate Age of Home: _____ years

Type of Construction: ___ brick ___ wood frame ____ other (specify)

Number of Floors (Above Grade): ___ 1 ___ 2 ___ 3

Number of Occupants: ___ 1 ___ 2 ___ 3 or more

Heating System: ___ electric baseboard ___ forced air ___ stove

___ other (specify) _____

Heating Fuel: ___ oil ___ wood ___ natural gas ___ electric

___ other (specify) _____

Foundation Construction: ___ fieldstone ___ concrete block

___ poured concrete ___ brick

___ other (specify) _____

General Condition ___ good ___ medium ___ poor

Basement Conditions:

Finished: ___ yes ___ no ___ partial

Regularly Used Living Space: ___ yes ___ no

Basement Floor Type: ___ concrete ___ dirt ___ other (specify) _____

General Condition ___ good ___ medium ___ poor

Floor Drain(s) Present: ___ yes ___ number ___ no

Sump Pit and Pump Present: ___ yes ___ no

Field Technician: _____, _____

Comments: _____

2.3.2 INDOOR RADON RESULTS

A total of 224 electrets were deployed to determine typical radon gas concentrations in Deloro Village homes. Of this total, only 2 electrets were found to have anomalous readings due to excessive voltage drop. This equates to an anomalous reading frequency of less than 1% and supports the selection of E-PERM radon monitors for use in this monitoring program.

Table 2.1 presents a statistical summary of the radon concentration data collected within the 57 Deloro Village homes. The mean concentration for a Deloro Village home main floor is 56 Bq/m^3, while the average for a basement area is 101 Bq/m^3. The maximum concentration measured in the 57 homes on the main floor was 284 Bq/m^3, while the maximum in a basement area was 392 Bq/m^3.

Table 2.1
Overview of Radon Concentrations For Deloro Village Homes Sampled During October 1998

Area of Home	Mean Conc. (Bq/m^3)	Maximum Conc.(Bq/m^3)	Minimum Conc.(Bq/m^3)	Number of Samples
2nd Floor	30	51	8	8
Main Floor	56	284	11	120
Basement	101	392	17	94

The collection of dwelling structural information (as presented on Figure 2.2) allows for more in depth examinations of the radon data by specific physical features. Table 2.2 presents examples of such data statistics (e.g. mean, maximum, minimum and number of measurements) for:

- specific ages of structures, and
- specific types of house construction (e.g. brick, wood, concrete block, etc.).

The database developed for this information within the Microsoft Access environment allows for a large number of individual queries to be developed, representing specific combinations of dwelling conditions that may be of potential scientific interest. Appendix C presents the radon data for the individual sites, while Appendix F contains the complete database of information on CD-ROM format.

Table 2.2
Summary of Interior Radon Concentrations
For Specific Physical Features

Category	Floor of home	Mean Conc. (Bq/m^3)	Maximum Conc. (Bq/m^3)	Minimum Conc. (Bq/m^3)	Number of Samples
Age of Home					
< 5 years	2nd	--	--	--	0
	main	17	17	17	2
	bsmt	21	25	17	2
6 to 15 yr	2nd	--	--	--	0
	main	85	143	11	6
	bsmt	138	148	125	6
16 to 25 yr	2nd	--	--	--	0
	main	157	273	15	8
	bsmt	209	392	26	8
26 to 50 yr	2nd	10	12	8	2
	main	31	102	6	12
	bsmt	95	235	22	6
> 50 yr	2nd	37	51	19	6
	main	50	284	12	90
	bsmt	89	237	20	74
House Construction					
Brick	2nd	--	--	--	0
	main	101	273	6	12
	bsmt	213	353	90	8
Conc. Block	2nd	--	--	--	0
	main	60	138	21	10
	bsmt	97	167	45	10
Wood Frame	2nd	30	51	8	8
	main	52	284	9	92
	bsmt	91	392	17	74
Mobile Home	main	23	23	22	2
	bsmt	34	35	33	2
Trailer	main	1	16	0	4

2.3.3 Indoor Gamma Radiation Results

At the time of E-PERM deployment and retrieval, gamma radiation measurements were taken in the general area of the E-PERM monitoring location. Table 2.3 presents a statistical summary of these interior gamma radiation measurements taken within the 57 Deloro Village homes. The average gamma radiation level for a Deloro Village home main floor is 5.00 µR/h, while the average for a basement area is 5.73 µR/h. The maximum gamma radiation level measured in the 57 homes on the main floor was 7.70 µR/h and the maximum in a basement area was 10.40 µR/h.

Table 2.3
Overview of Indoor Gamma Radiation Levels
Within Deloro Village Homes Sampled During October 1998

Area of Home	Mean Gamma. (µR/h)	Maximum Gamma (µR/h)	Minimum Gamma (µR/h)	Number of Samples
2nd Floor	4.15	4.85	3.83	4
Main Floor	5.00	7.70	3.26	57
Basement	5.73	10.4	2.82	47

2.4 Outdoor Ambient Radon

2.4.1 Sampling Program and Locations

The E-PERM technology and methodology described in 2.2 was used to measure concentrations of radon in ambient outdoor air. E-PERMs were deployed at the 11 ambient air monitoring stations selected by CG&S (i.e. dustfall and suspended particulate samplers were also deployed at most of these locations). Each monitor comprised a lockable metal or wooden housing with a grate-like bottom mounted on a metal post, with the base of the housing at a height of 1 to 1.5 metres above the ground surface (i.e. within typical breathing zone). The design of the monitoring stations afforded protection from the elements, safety to the monitoring devices and the free passage of ambient air to the E-PERMs.

The E-PERMs used for outdoor radon determination were deployed within the protective shelters for a period of approximately 4 weeks (e.g. 16 October to 13 November 1998). A total of 4 E-PERMs were deployed in each shelter (2 for radon determination and 2 for background gamma radiation).

2.4.2 OUTDOOR RADON RESULTS

A total of 44 electrets were deployed to determine typical outdoor gas concentrations in Deloro Village. Of this total, only 1 electret was found to have anomalous readings due to excessive voltage drop. This equates to an anomalous reading frequency of approximately 2.3% and supports the selection of E-PERM radon monitors for use in this monitoring program.

The results of the ambient radon monitoring are presented on Table 2.4. Ambient radon levels range from the effective reporting limit of 10 Bq/m^3 at most stations, to a high of 28.9 Bq/m^3 at Station 11 (vacant lot near main entrance to former mine site). The negative results presented in Table 2.4 reflect the uncertainty and variability in the differences of measured values between the open (responding to both radon and gamma radiation levels) and closed (gamma radiation only) detectors. This is a statistically appropriate method for reporting raw data, even if negative concentrations are a physical impossibility. A reporting limit of 10 Bq/m^3 has been applied to these data for outdoor radon.

Table 2.4
Results of Ambient Outdoor Radon Monitoring

Station Number and Location ID	Gamma Radiation (µR/h) *	Monitor 1 (Bq/m^3)	Monitor 2 (Bq/m^3)	Avg. Conc. (Bq/m^3)	Reported Conc. (Bq/m^3)
#1 - l	10.7	3.5	2.9	3.2	10
#2 - g	7.0	-2.6	3.0	0.2	10
#3 - v	8.4	4.0	4.4	4.2	10
#4 - z	6.9	7.3	6.4	6.9	10
#5 - ak	7.7	-3.7	n/a	-3.7	10
#6 - bb	5.9	3.5	0.2	1.9	10
#7 - bp	5.9	3.5	-0.4	1.6	10
#8 - bw	6.6	2.0	4.6	3.3	10
#9 - b	6.4	-4.6	-3.0	-3.8	10
#10 -a	3.9	-2.8	0.3	-1.3	10
#11 - da	102.8	15.3	28.9	22.1	22

Notes: Negative value denotes results for ambient gamma radiation greater than those for ambient radon and reflects uncertainty and variability in the difference of measured values between open and closed detectors.
n/a denotes data not available (dirt on electret)

* average of deployment and retrieval gamma radiation measurements as measured by scintillometer.

3.0 GAMMA RADIATION SURVEY PROGRAM

3.1 GENERAL

Naturally occurring above-background levels of gamma radiation can be found in areas where soils and rock contain uranium, granite, shale or phosphate. Elevated gamma radiation levels can also be found in soils affected by certain types of industrial waste and residues, such as those from uranium and phosphate mining and refining operations. As noted previously, historical operations at the Deloro mine site involved the reprocessing of uranium and radium residues for the recovery of cobalt and other metals. As a result, some of the slag-type wastes from these recovery operations have above background levels of gamma radiation.

As part of the 1998 environmental radiation monitoring program, gamma radiation levels were measured across the outdoor surfaces of participating private properties to document off-site levels of gross gamma radiation from terrestrial sources only (i.e. does not include cosmic component). No radiation surveys were conducted over roadways. The purpose of this component of the monitoring program was to determine typical gamma radiation levels within the Village and to provide estimates of potential radiation exposures rates. No attempt was made to discern the origin of any above background gamma radiation levels discovered during the surveys; however, close proximity to previously identified areas of elevated gamma radiation on the former mine site was noted as a significant contributing factor in the southeast portion of the study area.

The instrumentation to conduct these measurements and the results of the surveys are presented in the following sections.

3.2 INSTRUMENTATION

Scintillometer radiation detectors were used to measure ambient outdoor gamma radiation levels on the participating residential properties and to provide estimates of potential radiation exposure rates. Scintillometers are well suited for this type of monitoring because of their reliability and sensitivity to minor variations in background gamma radiation levels. These scintillometers were connected to individual recording and analyzing instruments (e.g. ratemeters, scalers, dataloggers, etc.) designed for specific types of applications required during the course of the Deloro Village investigations. The individual radiation monitoring systems used during the 1998 program in Deloro are described below. It should be noted, that each of these systems had been previously developed and used by SENES and the LLRWMO for other investigative programs in Canada and were considered to be suitable for this particular investigation in the Village of Deloro. The

systems all utilize scintillometer detectors mounted at heights of either 15 cm or 100 cm above the surface of the ground. All the systems provide reliable and accurate measurements of ambient gamma radiation exposure rates needed for the health risk assessment report (e.g. accurate measurement for large area sources). The scintillometers used in the investigation were calibrated against Ra-226 standards by the Low-Level Radioactive Waste Management Office at its Port Hope Field Services Office.

3.2.1 Large Area Gamma Survey (LAGS) System

The Large Area Gamma Survey (LAGS) system or "cart" is a portable computer-assisted radiation monitoring system that utilizes two Eberline SPA-3 (50 mm by 50 mm sodium iodide) scintillometer probes connected to Eberline SRM-300 ratemeters. The calibration constant for the LAGS system of 20 cps/μR/h used for the conversion of field data to exposure rate data was developed by the LLRWMO. The development of this constant was based on field testing of the exposure rate sensitivities for ten SPA-3 scintillation probes. This testing indicated that the mean sensitivity was 20 cps/μR/h for the interpretation of field data collected with the LAGS system.

The SPA-3 scintillation probes are mounted on each side of the cart at a height of approximately 15 cm above the ground. The carts are equipped with wheels so that they can be rolled over the surface of the ground. The LAGS cart system works well for the collection of gamma radiation data over ground surfaces where the large-wheeled cart can be easily pushed, and for site configurations where survey grid lines can be easily established.

The LAGS cart system is configured in such a manner that gamma radiation readings measured by the individual probes are retrieved every second from the SRM-300 units by a lap-top computer carried on the cart. The cart is pushed at a rate of 1 metre per second along grid lines established over the surface of the property to be surveyed. A specially designed computer program (SURVEY4) assigns the data to specific grid points for the site and stores the information in a unique computer file for the property. At the completion of the survey, the SURVEY4 file(s) for the property is compiled and analyzed for any radiation anomalies that may have been detected during the survey. Hand-held radiation detection instruments are used to follow-up and verify existence of the indicated anomaly.

To allow the compilation of the individual SURVEY4 property files into one database for the project, a Master Survey Grid for the Village of Deloro was established using Deloro and O'Brien Roads as the East-West and North-South axes, respectively. The centre of the intersection of these two roads was designated as 1000 m North and 1000 m East for this master grid. Markings were placed at 30 metre intervals along the centre of the roadways to assist the field crews in

establishing the individual site grids. This master survey grid was subsequently "tied-in" to the universal transverse mercator (UTM 18) coordinates for the area based upon the NAD 83 datum.

3.2.2 Roving GPS/Gamma Survey (RGPSGS) System

For portions of the investigation area that could not be effectively surveyed by the LAGS cart system, a portable global positioning system (GPS) was coupled to a portable gamma radiation meter to create a roving gamma survey system. The portable gamma radiation instrument used was a Ludlum 2221 single channel analyzer connected to a 50 mm by 50 mm sodium iodide crystal scintillation probe. For measurements performed with the GPS/Ludlum system a conversion factor of 1355 CPM/μR/h was derived through experimentation using a Ra-226 calibration source maintained by the LLRWMO Port Hope Field Services Office. The integrated data from the Ludlum detector was captured by the GPS system at 2 second intervals through a RS-232 interface and linked to the specific UTM coordinates for the surveyed location within an electronic rover file compiled by the GPS recording system.

The use of the RGPSGS system requires good sky view (i.e. ability for the GPS system to see the sky and receive satellite signals). Tree foliage and building overhangs can often impede sky view; however, in the case of this 1998 survey, the field work was conducted during the latter part of October and many of the leaves had fallen from the trees, providing better sky conditions than were originally anticipated for the survey.

3.2.3 Hand-Held Gamma Surveys

For some sites within the study area with heavy tree growth, it was not possible to use either the LAGS cart or Roving GPS systems to conduct radiation surveys on the site. For these sites, hand held radiation detection instruments such as the Eberline ESP-2 (coupled to a SPA-8 probe) or an Eberline PRM-7 were used to make spot measurements. These detectors use 25 mm by 25 mm sodium iodide crystal scintillation probes. The ESP-2 system was set up to integrate the count rate over a 10 second interval, while the PRM-7 provided a direct readout on an analog scale. Gamma radiation readings from these hand-held survey meters were written directly into log books or onto field sketches of the survey area. These data were subsequently entered into the electronic database for the monitoring program.

3.2.4 Portable Gamma Spectrometer Surveys

To complement the surface gamma radiation surveys of both the residential and open space areas, portable gamma spectrometer measurements were taken using an Exploranium GR-256. These

gamma spec measurements were taken at 21 locations throughout the Village to document typical potassium, uranium and thorium concentrations in area soils.

3.3 Surface Gamma Radiation Survey Program and Locations

Surface gamma radiation surveys were performed on participating open residential and public areas using the LAGS cart system. Surveys on these properties were performed along lines spaced approximately 1 metre apart to yield an approximate data density of 2 readings/m^2.

On these properties, positioning was performed using dead reckoning techniques tied into the Master Grid using measuring tapes, survey stakes and ropes. These location data were subsequently adjusted during the data analysis operation to place them on the global UTM coordinate system (i.e. UTM 18 NAD 83).

For residential properties lying outside the main Village that could not be tied into the Master Grid for the project, a local or "site-specific" survey grid was established on the occupied portion of the site. A minimum of 3 marked reference points on the grid were established (typically the origin and 2 corners) and each of these points were subsequently located using the roving GPS system. Similar to the master grid surveys, the location data for the local survey grids were adjusted during the analysis operation to place them on the global UTM coordinate system (i.e. UTM 18 NAD 83).

Gamma radiation surveys of areas within the Village with restricted access (thick vegetation or rugged terrain) were performed using manual techniques. Measurements of gamma radiation were taken using hand held scintillometers at selected locations along approximately parallel lines running perpendicular to O'Brien Road spaced approximately 10 metres apart.

Gamma surveys LAGS cart system were conducted on 63 participating residential properties within the study area. In addition to these private residential properties, LAGS surveys were also conducted on i) the Village's park area and baseball field located to the west of O'Brien Road, ii) on the property in the immediate vicinity of the Deloro Pump House, iii) on the yard area to the rear of the Community Hall/Library building, and iv) on the accessible portions of the vacant lot near the main gate to the former mine site.

Roving GPS gamma surveys were conducted i) along the rear laneway east of O'Brien Road, ii) along portions of the rear laneway to the west of O'Brien Road, iii) along the roadway leading to the private residence at 100 Deloro Dam Road, iv) along the series of recreational trails located to the east of the main Village, and v) along the western perimeter fence line of the

former mine site between the northern recreational trail area to the main gate into the site. In addition to the 5 areas noted above, roving GPS gamma surveys were also conducted in several of the open fields adjacent to the homes in the northern part of the study area. Roving GPS gamma surveys were also conducted on portions of large private properties that were not surveyed with the LAGS system.

3.4 Survey Results

3.4.1 Gamma Radiation

The results of the exterior gamma radiation surveys conducted on participating residential properties within the study area are presented graphically on Figure 3.1. This figure includes the results of LAGS cart surveys, roving GPS gamma surveys and handheld measurements taken in the heavily forested areas north of the main Village. The legend on Figure 3.1 depicts the specific ranges of gamma radiation that correspond to the individual colours presented.

Over 175,000 gamma radiation measurements were recorded during the course of the 1998 investigations. Table 3.1 presents a summary of the data, while Appendix D contains the results for individual properties. The mean of the 63 participating residential properties surveyed is 6.7 μ(micro)R(roentgen)/h with individual property average gamma radiation levels ranging from a low of 5.1 μR/hr (for site bi) to a high of 9.9 μR/h (for site k). For the vacant lot near the main gate to the former mine site, the average gamma radiation level is 47.9 μR/h with recorded levels ranging from a low of 11.7 μR/h to a high of 467.7 μR/h. The average gamma radiation level for the recreational trail area north and east of the main Village is 7.1 μR/h, with gamma levels ranging from a low of 3.0 μR/h to a recorded high of 54.8 μR/h. Within the park and baseball field area located to the west of O'Brien Road, the average gamma radiation level is 6.8 μR/h and ranges from a low of 2.6 μR/h to a high of 48.8 μR/h.

Three localized areas with elevated gamma radiation levels were found during the investigations of the participating residential properties within the Village of Deloro. One area (approximately 2 m by 2 m in size) is near the baseball field area. The contact gamma radiation level at this location is approximately 50 μR/h, with a gamma radiation level of 14 μR/h at a height of 1 metre above the ground surface. The second area (approximately 3 m by 5 m in size) is near the driveway of site l. The contact gamma radiation level at this location is approximately 80 μR/h, with a gamma radiation level of 26 μR/h at a height of 1 metre above the ground surface. The third localized area (approximately 2 m by 2 m in size) is to the rear of site j. The contact gamma radiation level at this location is approximately 100 μR/h, with a gamma radiation level of 15 μR/h at a height of 1 metre above the ground surface.

During the investigations of the rear laneways and recreational trails, a localized area with an elevated gamma radiation level was found in the vicinity of the former landfill site located approximately midway along the eastern laneway behind O'Brien Road. The maximum gamma radiation level measured was 55 μR/hr at a height of approximately 1 metre above the ground surface.

Table 3.1
Overview Statistics For Gamma Radiation Surveys

Site or Area	Mean Gamma (μR/hr)	Max Gamma (μR/hr)	Min Gamma (μR/hr)	Number of Measurements
63 residential sites	6.7	55.5	< 3.0	135,678
Baseball field & Village park	6.8	48.7	2.6	18,614
Community Centre & Library	7.5	15.9	3.0	9,666
Wooded lots north of main Village	6.0	9.0	4.0	464
Deloro Pump House property	7.4	11.0	< 3.0	1,606
West mine site fenceline	9.7	100.8	4.4	405
Vacant lot near mine site	47.9	467.7	11.7	1,378
East laneway behind O'Brien	6.5	9.0	3.9	223
Recreational trails	7.1	54.8	3.0	2,119
Deloro Dam roadway	4.8	6.7	3.3	135

In addition to Figure 3.1, the following colour gamma survey plots have been prepared to assist in the interpretation of the gamma radiation data gathered during the October 1998 field program:

Figure 3.2 Southern Block - presents the results for the area near the main gate to the former mine site, the homes on Private Road and Deloro Road, the library and community centre property, and the homes near the intersection of Deloro and O'Brien Roads. The radiation shine from the former mine site is quite evident on this figure.

Figure 3.3 Eastern Block and Wooded Area - presents the results for the recreational trail area east and north of the Village, as well as the area along the west perimeter former mine site fence.

Figure 3.4 Central Block - presents the results for the main Village.

Figure 3.5 Northern Block - presents the results for the 5 participating residential properties of the Village.

3.4.2 Portable Gamma Spectrometer

Portable gamma spectrometer readings were taken at 21 sites throughout the Village. Table 3.2 presents the results along with a statistical summary. The mean concentrations for potassium, uranium and thorium were 1.8 %, 1.5 ppm and 4.4 ppm, respectively.

Table 3.2
Portable Gamma Spectrometer Results

Location ID	Spectrum Number	Potassium (%)	Uranium (ppm)	Thorium (ppm)
rc	1	2.3	1.8	5.5
br	2	1.7	1.3	4.7
bt	3	1.6	1.2	4.5
bs	4	1.6	1.3	3.9
bv	5	2.4	1.6	4.8
bv	6	2.3	1.4	4.1
rh	7	2.5	1.6	5.2
rg	8	2.3	1.6	5.4
rf	9	2.1	1.2	4.6
re	10	2.3	1.7	4.0
bz	11	1.7	1.8	3.4
rb	12	1.6	1.6	3.4
ri	13	2.1	1.2	4.5
ra	14	1.6	1.5	3.5
rk	15	1.9	20.0	5.0
rd	16	2.1	1.6	3.9
pa	17	2.2	1.8	5.2
pb	18	2.6	1.5	5.4
pc	19	1.2	1.5	4.1

Location ID	Spectrum Number	Potassium (%)	Uranium (ppm)	Thorium (ppm)
bz	20	1.4	1.9	3.9
rj	21	1.3	1.1	3.5
	Average	1.8	1.5 *	4.4
	Maximum	2.6	20.0	5.5
	Minimum	1.2	1.1	3.4

Note: * average does not include uranium value for spectrum 15.

Figure 3.1
Deloro Gamma Survey - Entire Area

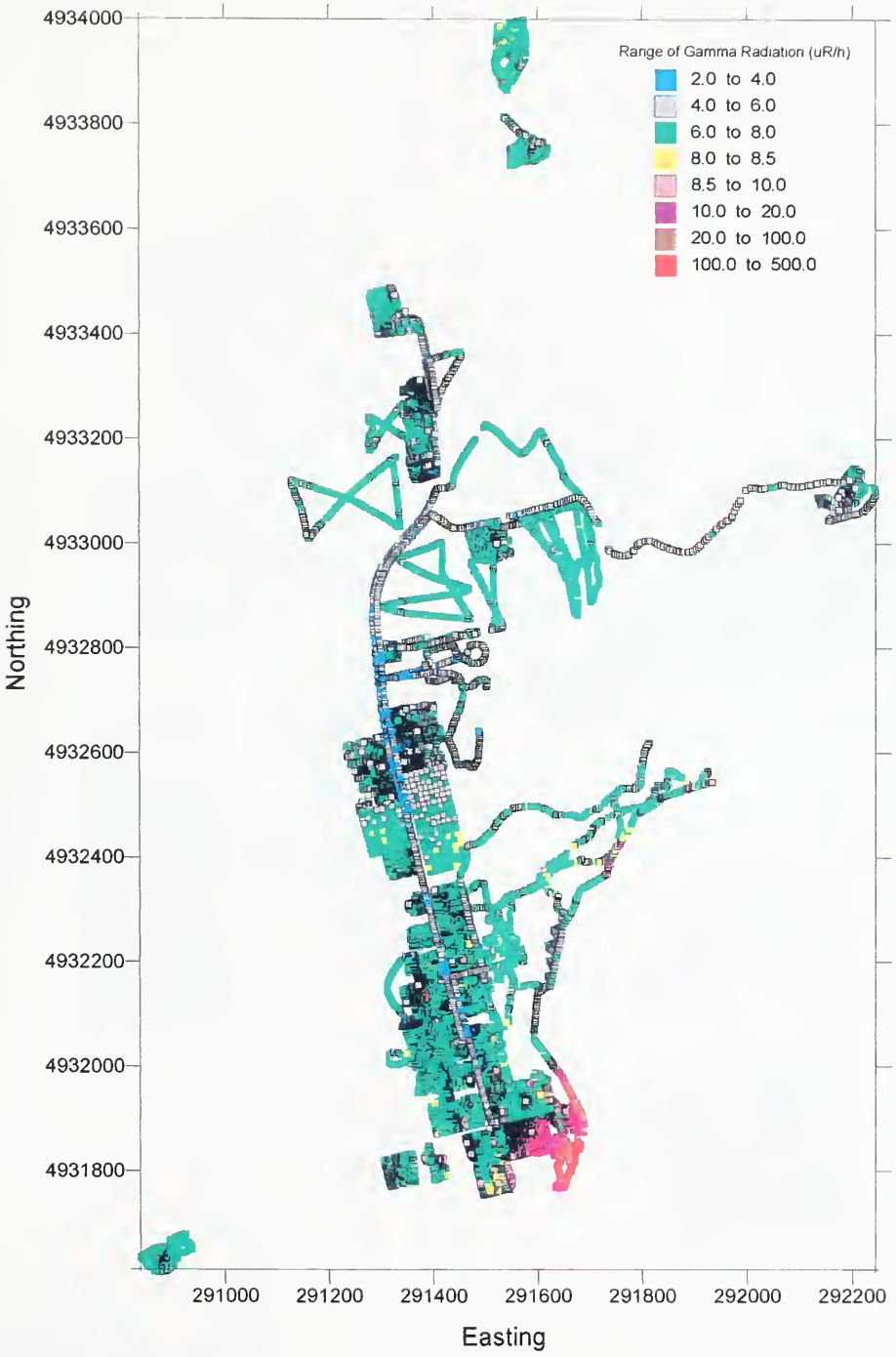


Figure 3.2
Deloro Gamma Survey - Southern Block

Figure 3.3
Deloro Gamma Survey - Eastern Block and Wooded Area

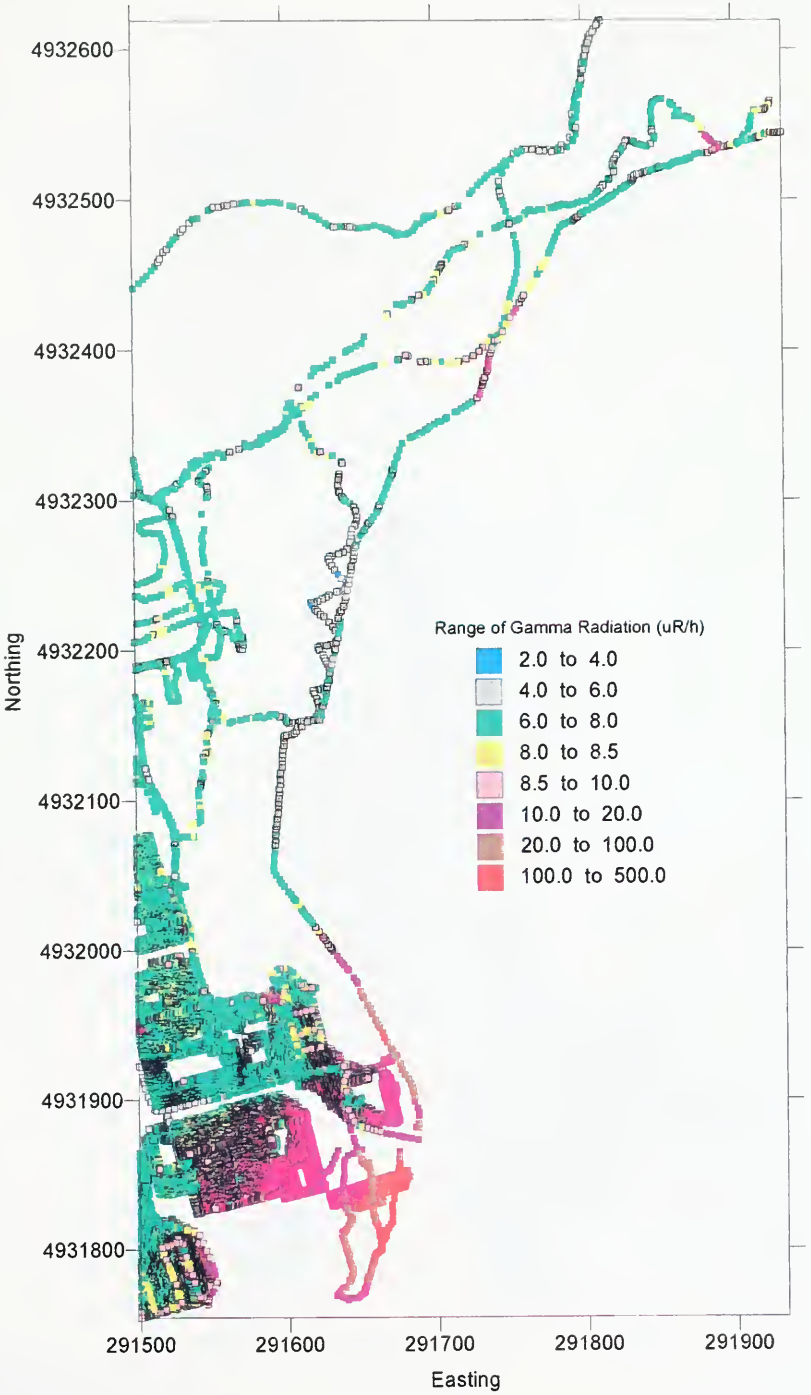


Figure 3.4
Deloro Gamma Survey - Central Block

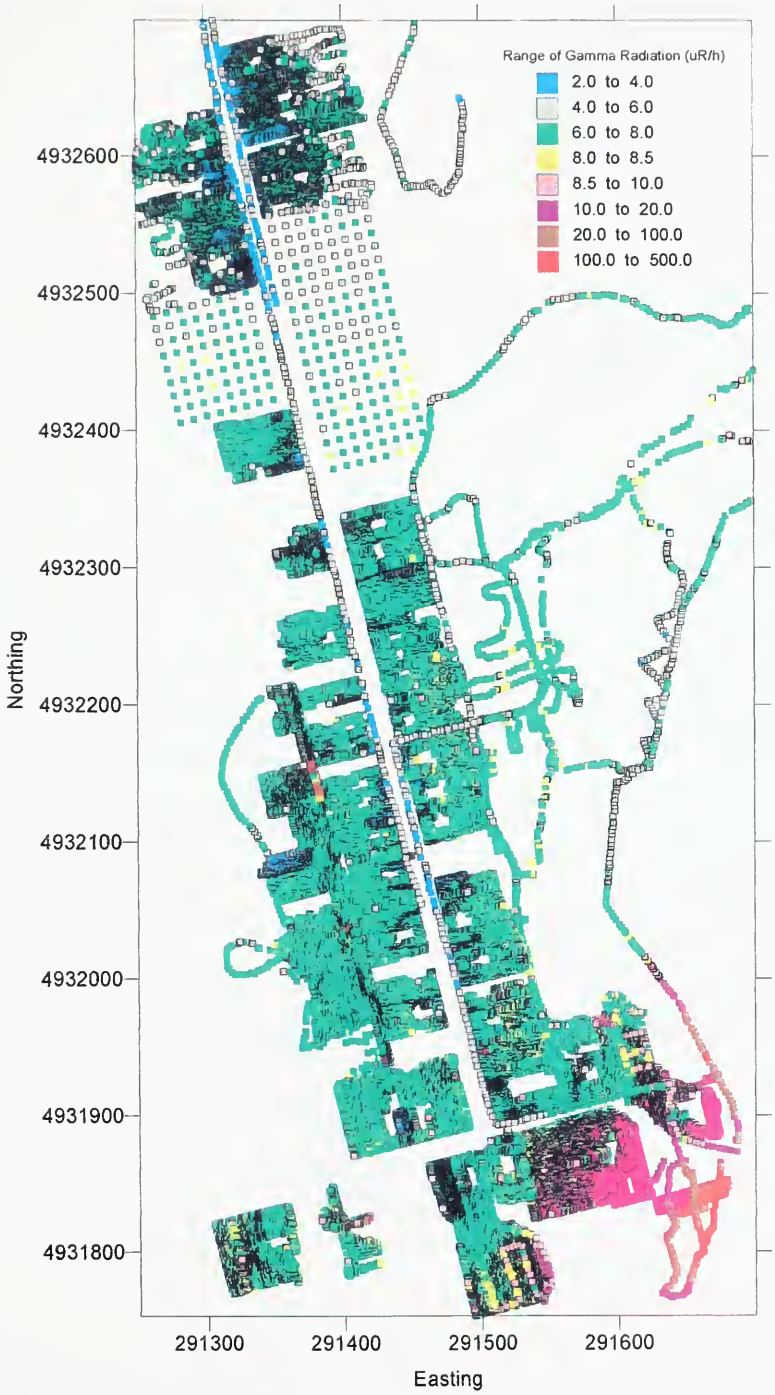
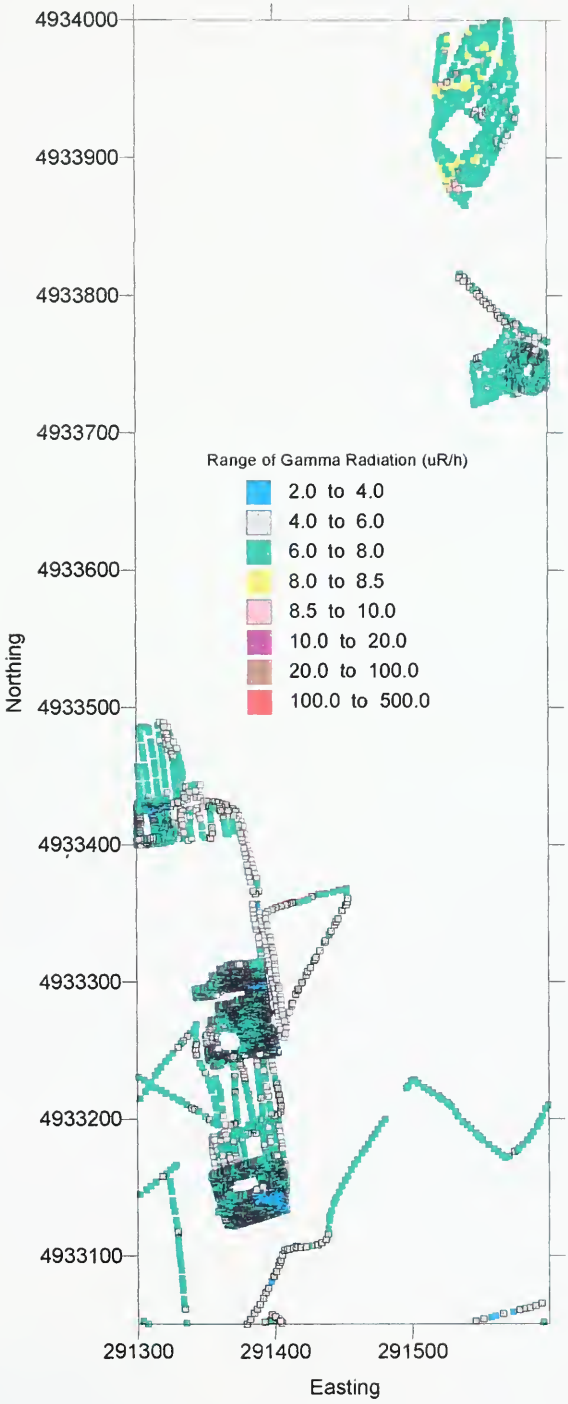


Figure 3.5
Deloro Gamma Survey - Northern Block



4.0 DISCUSSION OF RESULTS

4.1 INDOOR RADON

Based on a review of the indoor radon gas data, the living areas of 10 residences and the Deloro Pump House have or may be close to having radon and corresponding radon progeny concentrations higher than the April 1977 Federal Provincial Task Force Criterion for radon of approximately 150 Bq/m^3, corresponding to a radon progeny level of 0.02 Working Levels. A summary of the results for these sites is presented on Table 4.1.

The 1977 criterion was used during the late 1970s radiological monitoring in Deloro to identify homes that required remedial actions to reduce radon concentrations. This criterion still remains in effect within the communities of Port Hope, Elliot Lake, the Farady area near Bancroft and the Wahnapitae area near Sudbury. The 1977 criterion sets the primary clean-up or remedial action level for radon progeny at 0.02 Working Levels (WL). Application of a conservative value of 0.5 for the equilibrium factor gives an approximate radon concentration equivalent of 150 Bq/m^3.

It should be noted that while the radon levels approached or exceeded the 1977 Federal/Provincial Task Force criterion, none of the measured values exceeded Health Canada's radon guideline; considered to represent a level at which remediation actions should be taken. The more recent 1988 radon guideline developed by Health Canada recommends that remedial actions be implemented if radon levels in indoor air, as an estimated annual average in a normal living area, are greater than 800 Bq/m^3. This guideline is an upper limit. Health Canada is of the opinion that at a radon level of 150 Bq/m^3 no remedial action is necessary. This level can also be considered as a goal for any remedial action in occupied housing with a radon concentration above this level. For this guideline, 800 Bq/m^3 is equivalent to 0.1 WL and 150 Bq/m^3 is equivalent to 0.02 Working Levels.

A review of the spatial distribution of these homes does not indicate a correlation between proximity to the former mine site and the measurement of higher radon gas concentrations in Deloro Village homes.

Table 4.1
Summary of Preliminary Radon Monitoring Results

Location ID	Living Area	Radon Conc. *(Bq/m3)*	WL based on 0.5 equilibrium factor	1977 Task Force Criteria Exceeded	Health Canada Guideline Exceeded
q					
Basement	yes	*(194)*	0.026	Yes	No
Main Floor	yes	*(36)*	0.005	No	No
s					
Basement	yes	*(145)*	0.019	No *	No
Main Floor	yes	*(88)*	0.012	No	No
t					
Basement	yes	*(163)*	0.022	Yes	No
Main Floor	yes	*(130)*	0.017	No	No
bb					
Basement	no	*(137)*	0.018	No	No
Main Floor	yes	*(137)*	0.018	No *	No
j					
Basement	yes	*(390)*	0.053	Yes	No
Main Floor	yes	*(263)*	0.036	Yes	No
f					
Basement	yes	*(134)*	0.018	No *	No
Main Floor	yes	*(53)*	0.007	No	No
c					
Basement	yes	*(224)*	0.030	Yes	No
Main Floor	yes	*(102)*	0.014	No	No
br					
Basement	yes	*(351)*	0.047	Yes	No
Main Floor	yes	*(271)*	0.037	Yes	No
bs					
Basement	no	*(184)*	0.025	Yes	No
Main Floor	yes	*(132)*	0.018	No *	No
bv					
Basement	yes	*(140)*	0.019	No *	No
Main Floor	yes	*(107)*	0.015	No	No
m					
Main Floor	no	*(282)*	0.038	Yes	No

Note: * denotes radon progeny exposure rate close to the 1977 Task Force criterion that may warrant follow-up investigation.

4.2 Outdoor Radon

There are no criteria for outdoor radon. The highest outdoor radon concentration (28.9 Bq/m^3) was measured on the vacant lot near the main entrance to the former mine site. A review of the individual results suggests that the typical ambient outdoor radon concentration for the study area is in the order of 10 Bq/m^3 (the effective reporting limit for the study). The levels are typical of Ontario background conditions. The data do not indicate a distinctive trend in concentrations versus distance from the former mine site.

4.3 Gamma Radiation

The 1977 Federal Provincial Task Force also established a primary criterion for gamma radiation outside buildings of 0.10 m(milli)R/h at a height of 1 metre above the ground. An exceedence of this criterion prompted remedial action to reduce levels to as low as reasonably achievable (ALARA), taking social and economic factors into consideration. This criterion was based on an annual exposure limit of 5 mSv. The pending reduction to the public (non-atomic radiation worker) dose limit by the Atomic Energy Control Board (AECB) to 1 mSv per year from the current 5 mSv per year, would reduce this criterion level to 0.02 mR/h (above background).

A review of the data indicates that the 1977 criterion is exceeded at one site, specifically the vacant lot near the main entrance to the former mine site. One metre above ground height gamma radiation levels on this site exceed the 1977 Task Force criteria along the eastern perimeter of the vacant lot. Gamma radiation level as high as 0.467 mR/h were recorded on the property by the roving GPS gamma survey system. Figure 3.2 depicts pictorially the gamma radiation levels encountered on the site and the localized area of above criterion readings.

As noted previously, Figures 3.1 to 3.5 depict pictorially the gamma radiation measurements collected during the October 1998 investigations. The colours were selected such that yellow represents gamma exposure rates that are at or near the estimated upper end of background levels. Most of the study area has gamma radiation levels within the range of background conditions.

Elevated gamma radiation levels are present predominantly in the southeastern corner of the study area, in the vicinity of the main gate to the former mine site. Much of the gamma radiation is attributed to gamma radiation shine from radioactive material located on the former mine site. Gamma radiation emitted from this source material travels through the air and increases the gamma radiation level in the southeastern corner of the study area. The range of influence of this material is limited and the gamma radiation levels decrease rapidly with distance and reach

background levels within a few hundred metres of the western site boundary.

As noted previously, other small areas of elevated gamma radiation are found within the study area. Three of these sites are found on residential private properties. Elevated radiation levels are also found in the former landfill site located midway along the laneway east of O'Brien Road. These elevated gamma radiation readings may be attributable to small pockets of radioactive material located at or near the surface.

APPENDIX A

DETAILED DESCRIPTION OF INSTRUMENTATION AND TYPES OF DATA COLLECTED DURING OCTOBER 1998 FIELD INVESTIGATIONS TO CHARACTERIZE DELORO LEVELS OF RADIATION EXPOSURE

APPENDIX A: DETAILED DESCRIPTION OF INSTRUMENTATION AND TYPES OF DATA COLLECTED DURING OCTOBER 1998 FIELD INVESTIGATIONS TO CHARACTERIZE DELORO LEVELS OF RADIATION EXPOSURE

Type of Measurement	General Type of Instrument Used	Specific Model of Instrument Used	Units for Measurement	Target Locations	Approximate Number of Measurements	Format in which Data was Collected
Gamma radiation	Scintillometers (sodium iodide detector)	Eberline SRM-300 [#243] with probe SPA-3 [#LLW05] Eberline SRM-300 [#246] with probe SPA-3 [#95-024] Eberline SRM-300 [#0338] with probe SPA-3 [#LLW02] Eberline SRM-300 [#101]with probe SPA-3 [#95-026][1]	Counts per Second (CPS)	Private properties Baseball field and playground	170,000	Electronic files (.sv4) 1 file/private property 7 files for the baseball field/playground
		Ludlum 2221 [#1484444] with probe 44-10 [#150809] connected to a Trimble Global Positioning System (GPS)	Counts per Minute (CPM)	Additional measurements on large private properties Former mine site fence line Various paths in the woodlot separating the former mine site from the private properties located east of O'Brien St. Various farm fields located north of Deloro Village Paths around the baseball field and playground areas Former Galloway property Other [2]	8,000	Electronic files (.ssf) 1 file/feature of interest (e.g. field, path)

Type of Measurement	General Type of Instrument Used	Specific Model of Instrument Used	Units for Measurement	Target Locations	Approximate Number of Measurements	Format in which Data was Collected
		Eberline ESP -2 [#00943] with probe SPA 8 [#10005]	microRoentgen per hour (μR/h)	Indoor radon locations (private homes) Outdoor radon locations PIC locations Other[3]	300	Paper various formats
		Eberline PRM 7 [#608]	microRoentgen per hour (μR/h)	Woodlot east and west of O'Brien St. PIC locations Other[4]	500	Paper various formats
		Eberline SRM-300 [#97-002] with probe SPA 8 [#LLW04]	Counts per Minute (CPM)	Outdoor radon location #6[5]	900	Electronic file (.csv) 1 file
	Pressurized Ionization Chamber (PIC)	Reuter-Stokes RSS-112 [# N-302, V-408]	microRoentgen per hour (μR/h)	Outdoor radon locations Other outdoor locations[6]	35	Paper specific data log sheet
	Portable Gamma Spectrometer	Exploranium GR-256 [1568]	Counts per unit time	Outdoor radon locations Other outdoor locations[7]	20	Paper specific data log sheet Electronic files (.asp) 1 file/location
Radon Gas	Electret	E-PERM^R (Electret-Passive Environmental Radon Monitors)	Bq/m^3	Indoor radon locations (private homes)[8] Outdoor radon locations[9]	300	Paper 1 specific data log sheet/indoor or outdoor location 1 record per card/E-PERM)
Physical Location	Global Positioning System (GPS)	Trimble Pathfinder Pro XRS TDC-2 Data Collector [#T224002233] Pro XRS Antenna [#T220113753]	UTM 18 NAD83 (metres)	Corners of properties on local grids Reference points on master grid Outdoor radon locations PIC locations	3,000	Electronic files (.ssf) 1 file/feature of interest (e.g. south-west corner, master grid points)
	Master Grid	Measuring Tape, Survey Stakes, Survey Ropes and Dead Reckoning	metres	Private properties Baseball field and playground	Difficult to evaluate[10]	Position was recorded along with other type of information (e.g. gamma radiation) and in the same format as this other information

Type of Measurement	General Type of Instrument Used	Specific Model of Instrument Used	Units for Measurement	Target Locations	Approximate Number of Measurements	Format in which Data was Collected
	Local Site Grids	Measuring Tape ,survey Stakes, Survey Ropes and Dead Reckoning	meters	Private properties	Difficult to evaluate[11]	Position was recorded along with other type of information (e.g. gamma radiation) and in the same format as this other information
Characteristics of Houses surveyed[12]	N/A (qualitative information)	N/A	N/A	Indoor radon locations	60	Paper 1 specific data log sheet/indoor location

Notes:

(I) Two SRM-300 units and SPA-3 probes were installed with the SPA-3 probes attached on each side of the LAGS cart approximately 15 cm above the ground. The carts were equipped with wheels such that they could be rolled on the ground. Gamma radiation measurements were taken every second by the SRM-300 and the carts were pused at approximately 1m/s, yielding a gamma radiation measurement approximately every metre along each survey line on the properties surveyed.

The Ludlum scintillometer/Trimble GPS system was used mainly to collect gamma radiation measurements in the study where the use of the LAGS cart system would have been impractical. Such areas include very large tracts of land, very rough terrain and any region of interest in Deloro that may or not be privately owned. On very large tracts, gamma radiation measurements could not have been collected efficiently within a reasonable period of time with the LAGS carts. Collection was however, feasible with the Ludlum/GPS system because the Ludlum/GPS system is more compact, more portable than the cart system and was usable on very rough terrain where use the LAGS cart would simply not have been feasible. The Ludlum probe was carried approximately 1 m above the ground surface during data collection.

In addition to being the only instrument used to measure gamma radiation levels in private homes in locations where the radon monitors were placed, this handheld portable instrument was used to collect information on gamma radiation levels as needed during the course of the outdoor surveys.

This handheld portable instrument was used to collect information on gamma radiation levels as needed during the course of the survey.

This instrument was used to automatically measure gamma radiation every 5 minutes at one specific location (outdoor radon location #6). This information was gathered in order to estimate temporal variability of gamma radiation. One of the factors contributing to the variation of radiation is the weather (e.g. barometric pressure, wind, precipitation).

The PIC instrument was used to gather data for the entire gamma spectra and to determine the gamma radiation exposure rate at selected locations..

The GR-256 was used to measure the natural distribution for radionuclides of interests (e.g. uranium, potassium and thorium).

Replicates monitors were placed at each location where the radon gas concentration was measured. Generally, radon

concentration was measured at two different locations in the house, i.e. on the ground floor and in the basement. If the basement was not accessible (e.g. there was no basement or there only was a crawl space), radon monitors were placed on the ground floor and on the first floor above ground. In instances where there was only a ground floor (e.g. a mobile home or a trailer), the radon gas concentration was measured at only one location. Thus, since replicates were taken at each sampling location , four (4) radon monitors were generally placed in each house surveyed. In houses only comprising a ground floor, only two radon monitors were deployed.

Replicate monitors were placed at each outdoor location tested. Two (replicates) sealed radon monitors were also used at each outdoor location tested. Thus, in total four (4) radon monitors (2 unsealed and 2 sealed) were placed at each outdoor location tested. The purpose of using sealed radon monitors is explained below. Generally, outdoor radon concentrations are much lower than indoor radon concentrations since radon will diffuse rapidly into the atmosphere as opposed to remaining confined in the semi-air-tight volume within a building. Consequently, radon gas concentrations can be more difficult to measure outdoors than indoors. In particular, radiation emitted by radon gas is of much lower magnitude than gamma radiation detectable with a scintillometer. Most of the radiation emitted by radon gas comes from its decay into alpha (α) particles and ions. Since both types of radiation can cause a voltage drop in the electret system used to measure radon gas, it is necessary to independently determine the contribution of gamma radiation to the total voltage drop in order to estimate thec radon gas concentration. Indoors, the amount of radiation contribution attributable to radon gas is greater than that from gamma radiation. It is possible to subtract the gamma radiation contribution measured with a scintillometer from the total amount of radiation detected by the electret system. However, this is not possible outdoors because the difference between the total radiation measured with the electret system and the gamma radiation measured with the scintillometer is of the same order of magnitude. The contribution of gamma radiation to the total radiation measured with the electret system consequently must be measured otherwise. Sealed radon monitors were used to evaluate the contribution of the gamma radiation..

(10) Approximately 34 permanently marked reference positions were used during the survey. Many additional reference points were marked temporarily during the survey. Survey ropes were used as needed to grid the terrain between the marked reference points.

(11) A minimum of 3 marked reference points per property was used. The reference points generally corresponded to corners of the properties surveyed. Survey ropes were used to grid the properties between the marked reference points.

(12) The characteristics were gathered by examination of the houses surveyed and through interviews with the owner/occupant. The information collected includes: age of the house, type of construction (e.g. brick, wood frame), number of floors, number of occupants, type of heating system (e.g. electric baseboards, forced air, stove), energy source (e.g. oil, wood, natural gas, electricity), type of foundation (e.g. fieldstone, concrete blocks, poured concrete), condition of foundation, type of basement (e.g. finished), use of basement (e.g. living space, storage area), basement floor type (e.g. dirt, concrete, gravel), condition of basement floor, presence of basement floor drains, presence of basement sump pit and pump, presence of crawl space, and presence of attic.

During the field work, data gathered by members of the SENES team were consolidated into one location at the end of every day (i.e. information gathered on paper was placed in one (1) binder and data collected electronically was placed on the hard drive of a specific laptop computer (NBK 5/120)). Backup copies of the electronic information were kept in different locations until all the data gathered on the laptop NBK 5/120 could be copied onto a magnetic tape. In addition, daily activities were summarized in a note book at the end of every day such that the work accomplished could be systematically compared to the work remaining for completion of the entire task. The summary of daily activities was also compared periodically to the records (electronic files or pieces of paper) in order to verify that no records were missing. The format in which each type of data gathered was collected is also presented in Table 1.

APPENDIX B

STRUCTURE AND CONTENT OF RADIATION DATABASE FOR OCTOBER 1998 RADIATION FIELD INVESTIGATIONS

APPENDIX B: STRUCTURE AND CONTENT OF RADIATION DATABASE FOR OCTOBER 1998 RADIATION FIELD INVESTIGATIONS

Data gathered during the 1998 Deloro survey was entered into a database (Microsoft Access file "Gamma&Radon.mdb"). The structure of the database is primarily based on the structure in which the data was collected. Table 2 lists the general content of the tables, queries and modules that compose this database.

Table 2

Structure and Content of the Database (Gamma&Radon.mdb) Containing Data Gathered for the 1998 Deloro Radiation Survey

Item	Form	Main Content
GamBall	Table	Raw (in CPS) and converted (in µR/h) gamma radiation measurements collected on the baseball field and the playground with the Eberline detectors installed on carts. This table was built from .sv4 files. Also contains position in the master grid and in the UTM coordinate systems. The UTM coordinates reported in this table were calculated, not measured.
GamElse	Table	Raw (in CPM) and converted (in µR/h) gamma radiation measurements taken at various locations in Deloro with the Ludlum 2221 connected to a Global Positioning System (GPS). Also contains position in the UTM coordinate system. This table was built from .ssf files.
GamHandHeld	Table	Raw (in µR/h) gamma radiation measurements taken with the handheld Eberline PRM 7 in the woodlots located north of 50 and 51 O'Brien Road. Also contains position in the master grid and in the UTM coordinate systems. The UTM coordinates reported in this table were calculated, not measured.
GamLrgPrp	Table	Raw (in CPM) and converted (in µR/h) gamma radiation measurements taken on large private properties with the Ludlum 2221 connected to a Global Positioning System (GPS). The information gathered in this table is complementary to information gathered on private properties with the cart systems and reported in the database tables "GamPropMaster" and "GamPropLocal". Also contains position in the UTM coordinate system. This table was built from .ssf files.
GamPropLocal	Table	Raw (in CPS) and converted (in µR/h) gamma radiation measurements collected with the Eberline detectors installed on carts on private properties for which a local grid was established. This table was built from .sv4 files. Also contains position in the local grids and in the UTM coordinate systems. The UTM coordinates reported in this table were calculated, not measured.

Item	Form	Main Content
GamPropMaster	Table	Raw (in CPS) and converted (in µR/h) gamma radiation measurements collected with the Eberline detectors installed on carts on private properties located on the master grid. This table was built from .sv4 files. Also contains position in the local grids and in the UTM coordinate systems. The UTM coordinates reported in this table were calculated, not measured.
GamVar	Table	Raw (in CPS) and converted (in µR/h) gamma radiation measurements taken with the Eberline SRM-300 at outdoor location #6 for automatic data acquisition. This table was built from the .csv file.
Pic1	Table	Raw (in µR/h) gamma radiation measurements collected with the PIC Reuter-Stokes RSS-112 at various outdoor locations including the outdoor radon locations. Also contains gamma radiation measurements taken with the Eberline ESP 2 at the same time and location as the PIC measurements.
Pic2	Table	Raw (in µR/h) gamma radiation measurements collected with the PIC Reuter-Stokes RSS-112 at various outdoor locations. Also contains gamma radiation measurements taken with the Eberline ESP 2, the Ludlum 2221 and the Eberline PRM 7 at the same time and location as the PIC measurements.
PicLocUTMGam	Table	Raw data on position of some of the locations where PIC measurements were taken. These positions were measured directly in the UTM coordinate system using the GPS. Also contains gamma radiation measurements corresponding to the position measurements.
RadHouse	Table	Raw data on interior and structural characteristics of houses surveyed.
RadLocUTM	Table	Raw data on position of the outdoor radon locations. These positions were measured directly in the UTM coordinate system using the GPS.
RadRDataIn	Table	Raw data collected to calculate indoor radon concentrations (e.g. voltages, times and gamma radiation measurements taken with the Eberline ESP 2) as well as calculated radon concentrations (in Bq/m^3). Radon concentrations were calculated by the Low-Level Radioactive Waste Management Office (LLRWMO).
RadRDataOut	Table	Raw data collected to calculate outdoor radon concentrations (e.g. voltages and times) as well as calculated radon concentrations (in Bq/m^3). Radon concentrations were calculated by the Low-Level Radioactive Waste Management Office (LLRWMO).

The main advantages of using a database to store and manipulate the data collected are listed below:

Confinement of all the data in one file;

Simplification of data manipulation since the information all exists in one file and since a database is designed to handle large amounts of information without running into memory problems;

Provides QA/QC by allowing automatic (as opposed to manual) queries of information using various identifiers (e.g. calculates average gamma radiation measurements by location ID). The number of manual operations is reduced by the use of the database, therefore, the risk of human errors in manipulating such large amount of information is reduced;

Provides flexibility when manipulating the data. The queries and modules that can be performed directly in the database allow mathematical operations and other types of data manipulations to be performed uniformly throughout the database.

Based on the information presented in this memorandum, SENES feels that the methodology employed to collect, manage, store and manipulate the information obtained during the Deloro survey results in a product that achieves QA/QC standards.

APPENDIX C

SUMMARY OF INTERIOR RADON DATA

Table C.1
Summary of Interior Radon Data (Bq/m³)

Location ID	Description	Average	Detector 1	Detector 2
e	basement	66	65	67
e	ground floor	33	27	39
f	basement	134.5	132	137
f	ground floor	53.5	51	56
g	basement	60.5	57	64
g	ground floor	74.5	68	81
h	basement	96	93	99
h	ground floor	53	53	53
b	basement	26.5	24	29
b	ground floor	20.5	18	23
c	basement	224	213	235
c	ground floor	102	102	102
bv	basement	140	140	140
bv	ground floor	107.5	104	111
bw	basement	34	33	35
bw	ground floor	22.5	22	23
by	basement	32.5	26	39
by	ground floor	19	15	23
bz	basement	21	17	25
bz	ground floor	17	17	17
p	basement	41.5	40	43
p	ground floor	26	24	28
q	basement	194.5	185	204
q	ground floor	36.5	36	37
r	basement	48.5	45	52
r	ground floor	22	21	23
s	basement	145.5	139	152
s	ground floor	88.5	87	90
t	basement	163	159	167
t	ground floor	130	122	138
u	basement	81.5	78	85

Location ID	Description	Average	Detector 1	Detector 2
u	ground floor	47.5	37	58
v	basement	78	77	79
v	ground floor	72	62	82
x	basement	102.5	98	107
x	ground floor	47.5	47	48
y	basement	96	91	101
y	ground floor	46	46	46
z	basement	121.5	121	122
z	ground floor	80.5	78	83
aa	basement	36	32	40
aa	ground floor	29	27	31
ac	basement	68	66	70
ac	ground floor	32.5	25	40
ae	basement	223	222	224
ae	ground floor	37	34	40
af	basement	47	40	54
af	ground floor	25.5	23	28
ag	ground floor	37.5	37	38
ah	basement	37	35	39
ah	ground floor	41	21	61
ai	2nd floor	20	19	21
ai	ground floor	17	17	17
ak	basement	37	37	37
ak	ground floor	19.5	18	21
al	basement	50	46	54
al	ground floor	32	31	33
am	2nd floor	48.5	46	51
am	ground floor	47	45	49
an	basement	79.5	78	81
an	ground floor	29.5	28	31
ao	basement	33	29	37
ao	ground floor	22.5	18	27
ap	basement	41.5	38	45
ap	ground floor	19.5	14	25

Location ID	Description	Average	Detector 1	Detector 2
aq	basement	86.5	84	89
aq	ground floor	39.5	38	41
ar	ground floor	25	24	26
at	basement	101.5	100	103
at	ground floor	47.5	47	48
au	basement	48.5	48	49
au	ground floor	51.5	51	52
av	2nd floor	41.5	41	42
av	ground floor	37.5	35	40
ax	2nd floor	9.9	7.8	12
ax	ground floor	10.15	9.3	11
ay	basement (back)	21	20	22
ay	ground floor	33	33	33
az	basement	66.5	58	75
az	ground floor	19.5	19	20
bb	basement	136.5	125	148
bb	ground floor	136	129	143
bf	basement	25.5	22	29
bf	ground floor	24	23	25
bh	basement	90	90	90
bh	ground floor	64.5	63	66
bi	ground floor	11.5	11	12
bj	ground floor			
bl	basement	71	71	71
bl	ground floor	65	60	70
bm	basement	21.5	20	23
bm	ground floor	13	12	14
bn	basement	49.5	48	51
bn	ground floor	32.5	31	34
bo	basement	75	71	79
bo	ground floor	44.5	43	46
bp	ground floor	15.5	15	16
br	basement	351	349	353
br	ground floor	271.5	270	273

Location ID	Description	Average	Detector 1	Detector 2
bs	basement	184.5	181	188
bs	ground floor	131.5	131	132
bt	basement	131.5	130	133
bt	ground floor	74	74	74
bu	basement	107	102	112
bu	ground floor	42	40	44
j	basement	390	388	392
j	ground floor	263	262	264
k	basement	229	221	237
k	ground floor	60	59	61
m	ground floor	281.5	279	284

APPENDIX D

SUMMARY OF EXTERIOR GAMMA DATA

SUMMARY OF EXTERIOR GAMMA DATA (μR/h)

(as measured by LAGS system)

Location	Average	Minimum	Maximum	# of Measurements
e	7.12	2.80	14.35	3858
f	7.51	2.80	10.20	3918
g	7.54	3.00	15.95	9966
h	7.48	4.20	12.65	1584
b	6.33	3.80	8.50	2235
c	7.95	3.90	21.90	5208
bv	6.35	3.50	9.45	1807
bw	7.02	4.65	9.35	1798
by	6.73	3.70	9.55	6934
bz	5.80	3.83	12.25	1934
p	7.69	4.25	10.75	1284
q	7.18	4.35	10.10	558
r	7.68	3.40	11.35	1320
s	6.66	3.50	10.39	524
u	6.89	3.80	10.20	1768
v	7.28	3.65	10.75	1168
x	6.96	3.50	10.60	1284
y	6.52	3.55	9.75	1128
ya	6.65	3.40	12.95	1046
z	6.51	3.20	9.35	2054
aa	6.58	3.00	19.60	2206
ab	6.81	3.75	9.95	1744
ac	6.47	2.45	9.34	1111
ae	6.82	4.30	9.45	1394
af	6.94	3.95	13.85	806
ag	6.55	3.20	9.70	1060
ah	6.87	3.50	9.60	844
ai	6.96	2.95	9.50	858
aj	7.20	3.15	21.40	898
ak	6.57	2.75	9.05	830
al	6.88	2.30	9.30	1000
am	6.36	3.35	9.50	805
an	7.72	5.25	10.05	860
ao	5.64	2.75	8.45	476
ap	6.82	2.85	12.80	1431
aq	6.77	4.05	9.50	874

Location	Average	Minimum	Maximum	# of Measurements
ar	7.52	3.95	10.35	1326
at	7.34	3.45	11.05	1748
au	6.46	3.55	8.65	794
av	7.38	4.60	10.50	1446
ax	6.60	4.20	9.60	1090
ay	6.95	3.50	13.35	2548
az	6.35	3.70	9.75	1394
bb	6.46	3.30	8.85	3206
bc	5.88	3.65	11.75	1510
bd	6.68	3.95	8.90	2528
bf	6.41	3.70	8.90	1965
bh	6.42	3.15	9.60	3928
bi	5.11	2.70	7.60	1626
bj	5.60	2.10	7.85	4041
bk	5.73	2.65	10.30	3260
bl	5.54	2.65	8.20	4327
bm	5.25	2.10	10.50	2487
bn	5.85	2.70	8.10	4155
bo	5.30	2.20	7.55	2150
bp	5.72	2.60	8.85	1425
br	5.46	2.45	8.55	3708
bs	5.69	2.85	14.35	1883
bt	5.57	2.90	12.30	2672
bu	6.03	3.20	8.75	1921
i	7.12	3.55	16.75	4838
j	7.85	3.80	55.45	3230
k	9.86	5.20	16.85	10782
l	9.07	5.44	32.25	5862
da	39.49	11.70	390.05	1192
m	7.36	3.60	10.95	1605

APPENDIX E

RESPONSE TO COMMENTS ON DRAFT REPORT

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APPENDIX E: RESPONSE TO COMMENTS ON DRAFT REPORT

E.1 INTRODUCTION

This appendix provides responses to comments from expert external reviewers on the draft of this environmental radiation monitoring report (December 1998). Some associated responses to comments on the preliminary draft SENES radiological risk assessment report (February 1999, now finalized as SENES 1999) are also included, although the majority of such responses are provided in SENES (1999). The appendix includes responses to comments from Dr. Henry Caplan of the University of Saskatchewan, Dr. Bliss Tracey of Health Canada, Mr Mark Gardiner of the Low-Level Radioactive Waste Management Office, Dr. Arthur Scott of the Radiation Protection Service, Ontario Ministry of Labour, and Mr. Jim Mahoney, MOE Eastern Region. A number of comments by the reviewers relate to the draft summary report prepared by CH2M Gore & Storrie Limited (CG&S). Responses to these comments are being considered separately by CG&S.

E.2 RESPONSE TO COMMENTS FROM DR. HENRY CAPLAN, UNIVERSITY OF SASKATCHEWAN

The following responses refer to the comments entitled "Comments on Deloro Reports – Henry S. Caplan – 6th June 1999." The responses are organized according to the headings given in Dr. Caplan's comments

Indoor Radon

"These measurements seem to have been well done and were carried out in a systematic manner. I presume that the E-PERM detector used was the SST with 210 ml capacity though this is not explicitly stated"

> Yes. Indoor radon monitoring was conducted with S-Chamber E-PERMs fitted with ST electrets. The capacity of the S chamber is 200 ml.

"Since Indoor Radon is the dominant contribution to dose, I sought to follow the calculations through for this case starting from the summary Table C.1 [of the data report]. I could not reproduce the overall average 56.6 (I got 75) in Table 2.2 of the [SENES] main report and got a bit higher "maximum". Similarly, the geometric mean for the overall case given as 39.3 in Table 2.1 came out to be 52. I am sure we are looking at different sets of data, but I would be happier if the discrepancy were reconciled."

> The risk assessment used the data for the first floor of the houses as the first floor is the main living area of almost all the residences in Deloro. This is more specifically described in the revised report.

"Turning now to the indoor radon "background"; on page 2-9 of [the SENES] main report three sets of data are mentioned; Cobourg, Sudbury and U.S. Sudbury is touted as the one which "may provide a better comparison to levels in Deloro". However Table 2.2 suggests that it is the U.S. data which have been used and presumably the distribution in Table 2.1 with its low geometric mean comes from that set too."

Both the Cobourg and Sudbury data were based on instantaneous (grab) measurements. Cobourg is on Lake Ontario (which would tend to lower concentrations relative to an inland site) and the Health Canada Sudbury data were taken under maximized conditions i.e. generally closed windows and doors, and often in basements. Consequently, the Sudbury results should not have been indicated as possibly " ...providing a better comparison to levels in Deloro." In order not to bias the "background" calculations high, the data from single family homes in the large U.S. study were used (which gives an average between the Cobourg and Sudbury results). This is described in the revised text.

Outdoor Radon

"I found these measurements unsatisfactory except that they show that the levels are low. Table 2.3 with its negative results is very ugly. Perhaps "track etch" detectors should have been used since they have the added advantage of insensitivity to gamma rays. Alternatively the E-PERM HST 960 ml might do the job with a longer exposure."

Even #11 for the [name deleted] property [nearest the former mine site] is suspect despite being significantly positive. For this case, I would like to see the raw values for both pairs since that area has high gamma background and the result may [be] the subtraction of two larger numbers.... The failure to obtain experimental values may not be important, since the distributions assumed in Table 2.1 of the main SENES report [for outdoor radon] seem reasonable."

The negative results for outdoor radon shown in the results report properly reflect the uncertainty and variability in the differences of measured values between the open (responding to both radon and gamma radiation levels) and closed (gamma radiation only) detectors. This is a statistically appropriate method for reporting raw data, even if negative concentrations are a physical impossibility. The risk assessment study assigned a reporting limit of 10 Bq/m^3 to the raw data when doing the dose and risk calculations.

The higher radon result for the property nearest the former mine site was indeed calculated from the difference between two larger numbers because the gamma radiation exposure rate measured at that location was elevated.

However, since both of the paired detectors gave comparable results, the reported value is likely valid. The gamma radiation levels at each outdoor radon monitoring location are now also shown in the results report.

With respect to the sampling methodology, the selection of the E-PERM SST system was based upon the long-standing successful monitoring program conducted around the waste management areas in Port Hope. Unfortunately the time restrictions placed on the monitoring program for Deloro only allowed a period of 30 days in which to conduct the entire program, therefore the E-PERM SST system was selected. Our previous experience in measuring background outdoor radon concentrations suggests that the exposure period was too short for the deployment of track-etch monitors (2 to 3 months typical exposure periods for these units).

The caption on Table 2.3 is confusing. The open detector measures the sum of gamma and radon, while the closed detector measures gamma only. Here the inaccuracy of the detectors in this low region makes it possible for the gamma only detector to have a higher reading that the sum detector. The failure to obtain experimental values may not be important, since the distributions assumed in Table 2.1 of the main SENES report seem reasonable.

The caption on Table 2.3 (now Table 2.4) has been edited and the table has had an additional column added for gamma data measured by a scintillometer at each location. The text notes that there were a total of 4 E-PERMs deployed in each shelter (2 for radon determination and 2 for background gamma radiation). Monitor 1 refers to first radon determination E-PERM, while Monitor refers to the second radon determination E-PERM.

Gamma Radiation Survey

"This survey was well conceived and carried out. The instrumentation used was excellent. However, I found it disconcerting that the units used were Roentgens rather than Rads (a factor of 1.14) which is most unusual. Indeed there is no mention of the calibration and checking of the instruments. Be that as it may, the group is to be commended for its thoroughness and in the finding of "hot spots.

I was very disappointed in the response to higher levels found in the Southeast section near the gate to the [former mine] site. A collimated detector would have quickly determined the amount of "shine" compared to the local contribution. This would also have helped find any "hot spots" concealed by the shine if it exists."

The selection of the gamma survey instrumentation used for the Deloro survey was based upon previous monitoring program experience in Port Hope

and Malvern, Ontario (historical LLRW sites resulting from previous radium and uranium processing activities). The core instrument for much of this previous work was the Eberline PRM-7 scintillometer (or an equivalent instrument), which reports in units of microroentgens/hour (μR/h). Most, if not all, previous surveys in the Deloro area have been conducted by both consultants and government staff using this instrument (or an equivalent). For consistency with this previous work, the same type of instruments (scintillometers) calibrated in terms of μR/h, were used for the 1998 monitoring program. The federal Low Level Radioactive Waste Management Office (LLRWMO) maintains radium-226 calibration standards at its field support lab in Port Hope. Gamma radiation instrument calibrations conducted at the LLRWMO Port Hope lab are based upon units of μR/h. A discussion on instrument calibration is provided in the final report.

With respect to "hot spot follow-up" using collimated detectors, the purpose of the monitoring program was to collect data on existing radiation exposure conditions within the off-site areas of the Village, i.e. not on the former mine site. The program was not designed to characterize the sources of the radioactivity. For this reason, no follow-up work was done; however, the MOE is planning to characterize the various hot-spot areas to assist in the design of effective remediation works to reduce potential exposure levels in the southeast portion of the Village.

Direct Mine Site Effects

"First, on page 4-4 [of the SENES] main text, there is a reference to a survey of the Mine Site itself (SCIMUS Inc 1999.) 'Gamma radiation fields averaged 74 and 109 μR/h in the Industrial and Young's Creek areas respectively.' It would be interesting to know how far these are from the off-site area where high gamma levels were detected. Then one could comment on the plausible contribution of the shine. The pet peeve is that nay location named in the report should appear on the maps. I am not even sure exactly where the [name deleted] property is.... ."

As noted above, the major objective of the gamma radiation and radon surveys in Deloro was to provide data on environmental levels for use in the radiological risk assessment. The surveys were not specifically designed to assess the source of the levels e.g. elevated indoor radon levels could be natural or possibly due to either sub-surface contamination or naturally elevated radium levels, or a host of other reasons. Similarly, directionally-shielded gamma radiation survey detectors were not used. The former mine site itself and potential remediation measures is the subject of a separate study report prepared by CG&S which gives details on the various site locations. However for perspective, the Young's Creek area is several hundred meters from the western fence line, while the industrial area is immediately adjacent to the fence line. This is now indicated in the risk report.

The sources of the elevated gamma radiation levels in the industrial area likely contribute to the measured off-site gamma radiation levels.

Confidentiality prevents the use of specific site identification. In fact, all references to individual properties and any specific addresses have been removed in the final results report, and a general area description is used in their place (e.g. "vacant lot near access gate to mine site"). Boundaries for the various designated areas are now presented in maps for the total investigation area.

"Thus the vague suggestion (SENES main page 5-1) of a gradient of outdoor radon across the town, is perhaps not warranted."

Agreed. The statement in the risk assessment report has been modified and now refers only to the elevated level adjacent to the former mine site.

Gamma Radiation Survey (revisited)

"On page 16 of the SENES Results report, it is stated that gamma ray spectra were measured. These are not reported anywhere even to say that there were no surprises".

The gamma spectrometry data for uranium, thorium and potassium as determined in the field using an Exploranium GR256 are now reported in the final results report.

"In the trivia department, on page 22 the highest measured gamma level was reported as 467μR/h but in Table D.1 the highest entry is 390μR/h."

The summary statistics for the individual residential lots, presented in Table D.1 of the results report, were based upon data collected using only the LAGS system and do not include data from the hand-held survey instruments or the roving GPS system. The LAGS data provided complete coverage of each property and were exclusively selected for the statistical summary to provide consistency in sampling methodology, instrumentation and sample height. However, for the data summary presented on Page 22 of the draft results report, the complete data set from all instruments were used. This is clarified in the final results report.

"For the measurements indoors, the gamma level was determined in order to subtract it from the E-PERM reading. I presume that these results were used to derive the distributions given in Table 2-1 of the main SENES report.

Yes. Indoor gamma radiation levels were measured using scintillometers (reporting in μR/h at the time of E-PERM deployment and retrieval. These data were used in the calculation of the indoor radon concentrations, and to represent indoor levels in the risk assessment report.

Radionuclides in Drinking Water

"In light of this, I was very surprised at the high values of doses (16% of total) attributed to this source [drinking water]... Unfortunately, someone has flipped the reporting limits for Pb-210 (0.5 Bq/l) and Po-210 (0.01 Bq/l). This makes a profound difference since Po-210 is an alpha emitter. In terms of the conclusions, this may not really matter as explained below."

As stated by Dr. Caplan, the reporting limits for Pb-210 and Po-210 were interchanged in the draft risk report. This has been corrected in Table 2.1 and in the dose and risk calculations. However, this does not make a profound difference to the results since the ingestion dose conversion factors (dose per unit intake) for Pb-210 and Po-210 are generally within a factor of about 2 of each other for all ages (Table 3.6 of the risk report). The revised results show that water contributes to about 11% of the dose and lifetime risk (Tables 4.1, 4.2 of the risk report). As explained in the text, the water dose is still overestimated because the measured values were below the reporting limits.

Suggested Inserts into the Reports

"I think that a paragraph should be inserted to explain the difference between "baseline" and background".

A paragraph has been inserted in Chapter 5 of the revised risk report.

"Let us return to the "water problem" mentioned above.... Thus even if the water borne dose were to go down by a factor of 10, the absolute difference between Deloro and background would remain the same, which implies the incremental risk remains the same. Of course, the fractions would be quite different."

As noted above, the estimated doses and contributions (fractions) to dose from drinking water were not profoundly different after correcting the Pb-210 and Po-210 reporting limits. The fractions changed from 16% in the draft risk report to 11% in the revised report. As suggested by Dr. Caplan, the absolute difference between Deloro and background was not affected by this change.

Other Channels

"I have not had time to analyze in detail the other channels e.g. dust in the air but I have confidence in the measurements made on them. No high levels were found and the doses will be low. This is the case where [SENES] uses background values higher than the measured values."

> Information on suitable background values for other locations were taken from the referenced sources. It does not seen unusual to us that the air concentrations measured in Deloro (for those above reporting limits) are lower than values measured elsewhere.

"I did notice that the statistical distributions suggested for radionuclides in the air in the CG&S reports were not the ones used by [SENES]"

> This comment is unclear. The CG&S reports do not suggest the type of distributions for radionuclides in air. The SENES report used the available data for Pb-210 and Po-210. (Concentrations of other radionuclides generally below reporting limits were estimated as explained in the text of the risk report.) The Po-210 values were corrected by SENES for decay and ingrowth from Pb-210 during the delay between sampling and analysis (in the order of 40 days) because of the 138 day half-life of Po-210. Because of the minor contributions to dose from airborne radionuclides (less than 1%), the assumed air concentrations had no perceptible impact on the dose and risk calculations.

Conversion of Levels to Exposure, Dose and Risk

"How were seasonal variations taken into account? For example in the winter, when the ground is frozen and there is perhaps 30 cm of snow on the ground, local contributions to outside radon are negligible and even the gammas are appreciably attenuated."

> It is recognized that seasonal variations are present in media concentrations and exposure rates. Rather than predict the concentrations and exposure rates for other seasons, the concentrations measured in Deloro during the "Fall" period were assumed to apply for the entire year. As noted by Dr. Caplan, this is considered "conservative" in that it likely overestimates doses from external gamma radiation and outdoor radon. The background measurements were typically based on annual average conditions; hence, doses and risk for Deloro are likely slightly overestimated relative to background conditions.

"Section 3.1.6 of [the SENES] main report describes "Activity Patterns". The mean time indoors was 115 hrs/week and the mean time outdoors was 14 hrs/week. What happened to the other 39 hours?"

> As indicated in the report, the activity patterns were based on the survey data obtained from Deloro residents. The activity patterns were intended to be consistent with the patterns used in the chemical risk assessment for exposure while in Deloro. The people spend a portion of their time outside of Deloro (e.g. at work, school, vacation, etc.). Doses and risks for times spent outside of Deloro were not included in the dose and risk estimates for either Deloro or background exposures.

"It is disconcerting to read, "A uniform distribution with bounds between the mean and plausible maximum was used to describe the data." I hope this really means, "A uniform distribution with the upper bound as the plausible maximum and the lower bound chosen to give the specified mean."

> The uniform distributions used in this assessment were assumed to range from a lower bound set equal to the mean value reported in the reference, to an upper bound set equal to the plausible maximum. The mean value of such a distribution will therefore be higher than the mean reported in the reference. The dose and risk estimates are therefore slightly conservative.

Aside

"I know it is fashionable to write reports in "plain language" but a major difficulty I have with this report is the lack of algebra."

> A more detailed appendix on the calculation methodology has been added to the risk report.

Return to Activity Patterns etc.

"I do not know how they dealt with the anti-correlations of these distributions. For example, the person with the maximum time indoors must have the minimum time outdoors. That person cannot have the maximum exposure in both."

> Time spent indoors and outdoors was considered uncorrelated in the analysis except for control by the age group. Since the modelled receptors do not spend all their time in Deloro (e.g. 24 h/d everyday), it is possible for the receptor to have both the maximum time indoors and the maximum time outdoors without exceeding 24 h/d.

"I have not checked the conversion factors for exposure to dose. However, I did notice that footnote b) in Table 3.7 has those dumb Roentgens again but with the conversion factor the wrong way round."

This typographical error has been corrected.

"The text talks of "sampling" the distributions but I do not know exactly what that means without the algebra. Is it some kind of Monte Carlo calculation?

The sampling in the probabilistic calculations was Monte Carlo selection from the input distributions using simple random sampling. This is now noted in the text. In addition, the methods and equations used to combine the sampled distributions are now described in Appendix C.

"However, it is not clear to me how summing over the zones to get "all Deloro" was done. Were the data weighted number of people resident in each zone?"

The "all Deloro" doses and risks were calculated using the overall distributions of the characterization measurements in Deloro i.e. these overall distributions were sampled to obtain the "all Deloro" results. The results from the individual zones were not agglomerated to produce the "all Deloro" estimates.

The Bottom Line

"I do not think that the conclusions will change much in the next iteration on the analysis. While the manner of presenting the results is fine, I do feel that more emphasis should be placed on the idea that the absolute incremental dose, if any, is smaller than 1 mSv."

The text in the risk report has been changed to note that the difference in estimated doses for all zones in Deloro (except Zone 4 closest to the former mine site) and "background" is less than 1 mSv/y. However, as now noted in Chapter 5, this difference should not be considered to necessarily provide an accurate estimate of incremental levels since the background distributions only approximate the Deloro baseline levels.

E.3 Response to Comments from Dr. Bliss Tracy, Health Canada

The following responses refer to comments from Dr. Bliss Tracy of Health Canada entitled "Deloro Village Health Risk Study"(undated).

"The two SENES reports (Environmental Radiation Monitoring and Radiological Health Risk Assessment) show methodologies and results that are quite thorough and quite adequate for the

purpose of the risk assessment. The overall conclusion of these reports appears to be well-founded, i.e., the radiation exposure of a Deloro resident falls within the range of general background exposures to Ontario residents."

"The radon readings are scattered and do not appear to be in any way correlated with distance from the mine site. The highest radon values (284 Bq/m^3 main floor and 392 Bq/m^3 basement) are not unusual in a geological formation in which mineralization is found. There is no indication that any radon levels are enhanced as a result of human activities in the area."

> Agreed, with the possible exception of the outdoor radon measurement at the location closest to the former mine site.

"There seem to be some confusion in the report as to which guideline should apply to remediation of the radon levels. The 1977 Federal Provincial Task Force criterion of 150 Bq/m^3 was derived specifically to deal with the clean-up of Port Hope properties that had been contaminated by historic wastes form the radium refining industry in that town. The criterion was also applied to radon mitigation in Elliot Lake homes, which had arguably been affected by the uranium mining operations there. Radon levels in Deloro are apparently not related to any mining or uranium operations. The Health Canada criterion of 800 Bq/m^3 would be more appropriate for radon levels due to purely natural sources."

> We agree with the comments on the intended applicability of the Task Force and Health Canada guidelines. However, because previous deliberations on indoor radon levels in Deloro had used the 1977 Task Force criterion as a basis for some remediation work in Deloro (e.g. Knight and Makepeace 1980), it was considered appropriate to refer to this criterion, as well as the more recent Health Canada criterion when discussing the radon measurements.

"All the gamma readings can be considered normal (averages of 5 to 7 μR/hr, maxima of 20 μR/hr or less) except for one or two locations very close to the mine site. The Federal Provincial Task Force Criterion of 100 μR/hr for remediation is probably too high by today's standards. Continuous exposure for 10,000 hours per year would lead to an annual dose of about 1 Rem or 10 mSv per year. This is ten times the public dose limit soon to be adopted in AECB regulations. Remediation measures should be undertaken for locations with gamma readings significantly greater than 20 μR/hr."

> It is agreed that the 1977 criterion was set when dose limits were higher. However, maximal continual exposure (generally considered to be 75% of the time or 6570 h/y) to an exposure rate of 100 μR/h from natural uranium radionuclides in the ground would lead to an annual dose of about 3.9 mSv/y. Average longer-term annual doses would be much lower. Nevertheless, the

MOE has indicated that any areas in the Deloro with exposure rates above 20 μR/h (immediately adjacent to the former mine site and in three very small pockets in the Village of Deloro) will undergo remediation.

"More analyses may be needed on home-grown produce. Metals and radionuclides present in the soil may not be translocated to vegetables grown in the soil."

Additional analyses may be beneficial as a research topic, but the very minor significance of this exposure pathway in Deloro (< 1% of total dose) indicates that further analyses of produce relative to potential exposures and risks to residents of Deloro are not required. The available radiological data on soil concentrations in Deloro indicate that soil concentrations are relatively low compared to typical background levels, and therefore would not produce elevated concentrations in the garden produce.

E.4 Response to Comments from Mark Gardiner, LLRWMO

The following responses refer to comments from Mr. Mark Gardiner of the Low-Level Radioactive Waste Management Office (LLRWMO) entitled "LLRWMO Review of the 'Report on the Results of Environmental Radiation Monitoring Conducted in Support of the Deloro Village Environmental Health Risk Assessment' (REF1)" (undated).

"Pg. 2: Add text identifying the number of potential properties/residences for both radon and gamma monitoring. An idea of how much coverage was obtained would be useful i reference."

Figure 1.1 delineates the study area and the text indicates that there are approximately 77 residential properties within the study area.

"Pg14, S3.1: Add text which includes a note stating that the gross gamma radiation readings were from terrestrial sources only, and do not include a cosmic component."

The text has been revised to reflect this comment.

"P17, S3.4: The median value is more important with regard to properties with relatively high gamma radiation readings [lot near former mine site]. The average is likely skewed due to a few high readings."

The number of individual data points on which the statistical results presented in this section are based range from a low of 524 to as high as 9966 per property. Based on this large number of points the effects of data skewing are likely minimized. For the specific site in question, over 1100 data points were collected.

"F3.1, 3.2 , 3.3, 3.4: The gamma data of the roadway is conspicuous in its absence; text should explain in a sentence, or so, why it was not done."

> The purpose of the monitoring program was to document gamma radiation levels on participating residential lots within the Village. The text has been revised to reflect the fact that roadways were not targeted areas for the gamma radiation surveys.

P20,S4.1,para "The FPTFR criterion should be dated April 1977."

> The text has been corrected to reflect this comment.

P20, S4.1, para2: "The LLRWMO uses the IAEA equilibrium ratio of 0.4. This ratio is also used as a reference in the "Radiological Health Risk Assessment for the Village of Deloro"

> For the identification of homes with potential radon and radon progeny levels above the FPTFR criterion that may require follow-up monitoring, a conservative equilibrium factor of 0.5 was used.

Table 4.1: "The purpose of applying a criteria to a data set is usually to determine whether a measurement or observation passes or fails. It is not the practice of the LLRWMO to classify such measurements as "Close". It is more appropriate to state pass/fail and use the text as a description of anything else remarkable about the data."

> The table has been revised to reflect this comment. Interior radon progeny levels approaching the FPTFR criterion are denoted in the table by a "*" which corresponds to a text description as a footnote to the table.

S4.3 para 1&2: "Some text describing prefixes μ(micro) vs m(milli) might be useful."

> The text has been revised to reflect this suggestion.

Table C.1 & D.1: "The tables need units to be associated with the values."

> The text has been revised to reflect this suggestion.

E.5 Response to Comments from Arthur Scott, Ministry of Labour

The following responses refer to comments from Arthur Scott of the Ontario Ministry of Labour, Radiation Protection Service, entitled "Review of Radiation Monitoring at Deloro." (22 June 1999).

"The report "The Results of Environmental Radiation Monitoring. . " does not include a Quality Assurance section covering the standardization and comparability of the different types of gamma survey equipment used. The survey goals, design and some of the data handling could also be in that section."

> The text has been modified to describe the survey goals for both the gamma radiation and radon gas monitoring programs. Instrument calibration and comparability of results between the types of gamma survey equipment used is also discussed. Appendix A describes in detail the types of instrumentation used for both monitoring programs.

Both the Federal Provincial Task Force Criterion of 0.02 WL (150-200 Bq/m^3) and the Health Canada Guideline of 800 Bq/m^3 are referenced. My opinion is that neither is applicable to this case. The Federal Provincial Task Force recommendations were for contaminated sites, but were specific to the sites examined, and the Task Force is disbanded. the Guideline is basically guidance for home owners dealing with natural radon, not contamination. To look ahead, if there are to be radon guidelines for Deloro, the Province will have to make them."

> We agree with the comments on the intended applicability of the Task Force and Health Canada guidelines. However, because previous deliberations on indoor radon levels in Deloro had used the 1977 Task Force criterion as a basis for some remediation work in Deloro (e.g. Knight and Makepeace 1980), it was considered appropriate to refer to this criterion, as well as the more recent Health Canada criterion when discussing the radon measurements.

The goals of the indoor radon survey are not clear. Was one to identify houses with high radon concentrations for further investigation to exclude contamination from mine materials c.f. [name deleted] property [nearest the former mine site]?

> The text has been modified to describe the survey goals for both the gamma radiation and radon gas monitoring programs. The purpose of both programs was to determine typical exposure levels within the Village. The monitoring results identified sites with potentially elevated levels of gamma radiation and radon gas; however, no further investigations to determine the nature and extent of the source were carried out as part of the 1998 monitoring program.

E.6 Response to Comments from Jim Mahoney, Ministry of Environment

The following responses refer to comments from Jim Mahoney of the Ontario Ministry of Environment, Regional Program Coordinator, Assistant Director's Office, Eastern Region, entitled "Summation of Comments - Deloro Environmental Health Risk Study Reports (16 June 1999), specifically the report entitled 'The Results of Environmental Radiation

Monitoring Conducted in Support of the Deloro Village Environmental Health Risk Assessment (SENES Consultants Limited -December 1998).

1. "Table 1.1 identifies 60 locations as participating in the indoor radon survey yet the accompanying text indicates that indoor radon concentrations were measured within 57 residences, the communal water supply pumphouse, and the Marmora Township Office (at total of 59 locations)."

The table has been corrected to reflect this comment. Radon was measured at a total of 59 indoor locations.

2. "When describing potential sources of radon and gamma radiation the report's author relays that the parameters may be '. . .found in high concentrations where soils and rock contain above background levels of uranium, granite, shale or phosphate. Radon [and gamma radiation] can also be found in soils affected by certain types of industrial waste and residues, such as those from uranium and phosphate mining and refining operations.'.

The report goes on to note that historical operations at the Deloro mine site involved the reprocessing of uranium an radium residues. In the absence of any discussion pertaining to the occurrence of conditions that could result in naturally occurring radon or gamma radiation the implication is that the source of radon and gamma radiation in Deloro is the mine site. Do the prescribed preconditions exist in Deloro for naturally occurring radon and gamma radiation? Is it the consultants intention to definitively link above background radon and gamma radiation measurements to historic activities at the mine site? "

The intent of this description was to demonstrate that natural as well industrial "materials" could be potential sources of radon and gamma radiation. There was no intent to definitively link above background radon and gamma radiation measurements in the Village to historic activities at the mine site. The text has been revised to clarify this issue.

3."In section 2.3.1 of the report it is indicated that paired E-PERM monitors are useful for screening out anomalous readings, which occur with a frequency of approximately 5%. There is no discussion provided that identifies the frequency of anomalous readings encountered in Deloro. If anomalous readings occurred in the Deloro survey, was the frequency of their occurrence less than or greater than the "typical" frequency of 5%. This information is significant with respect to establishing the credibility of the data collected."

The frequency of anomalous for the interior radon monitoring program was less than 1% (2 monitors out of 224) and 2.3% (1 in 44) for outdoor radon monitors. The text has been revised to present these acceptable frequencies.

4. "The E-PERMs positioned in residences were in place during the period from October 19-21, 1998 to November 2-3 1998. Information relayed in a teleconference involving the consultant is significant and should appear in the report. During a teleconference the consultant suggested that the radon readings collected are likely to represent maximum values because the data was collected during a period when windows were closed and heating systems were yet to be in full use (i.e. the period of poorest air circulation within homes and reduced air transfer from homes)."

Poor air circulation and reduced air transfers from homes can result in elevated radon levels. In the fall of the year, these conditions can occur in a home when residents minimize the influx of outside air (keep doors and windows closed) and do not need to use their heating systems (which can result in poor air circulation within the home). The latter half of October in 1998 (during which the sampling took place) was mild and these conditions could have occurred in many of the homes monitored. The text has been revised to reflect these potential conditions leading to maximized radon levels in Village homes.

5. "Table 2.2 suggests that dwellings constructed 16 to 25 years ago have the highest mean radon levels in the basement and main floor levels. There is no interpretation offered as to why homes that are less that 16 years old or greater that 25 years old tend to have lower concentrations of radon. Is this an indicator of poor construction techniques or materials used by a builder that was active at that? Were the homes that were built 16 to 25 years ago constructed in a manner that reduces air circulation? Are the homes in this age range clustered together in a high ambient radon area?

Likewise, is there any significance to the fact that brick homes tend to have higher mean radon levels in their basement and main floor levels that homes constructed of other materials?"

Table 2.2 was presented as an example of how dwelling information gathered during the monitoring program could be used to examine potential correlations between structure age and construction. There was no intent in this report to draw any inferences from the collected structure data.

6. With respect to radon, the report never comments upon a relationship between elevated readings and proximity to the Deloro mine Site.

A review of the locations for the 10 homes with potentially elevated readings in context with proximity to the mine site does not indicate any relationship. The report has been revised to address this comment.

7. A footnote should be provided for Table 2.1 that identifies the radon criterion cited by the 1977 Federal Provincial Task Force and the Health Canada guideline.

The author believes that Table 2.1 is not the correct place to introduce a footnote pertaining to the Federal Provincial Task Force criterion and the Health Canada guideline. They are more appropriately introduced and discussed in Section 4.

8. "The height above ground surface at which gamma radiation readings are collected appears to be significant yet there was variation evident in the techniques used to collect data in Deloro. It is indicated that the E-PERMs deployed for outdoor radon and background gamma radiation measurements were mounted 1 to 1.5 m above the ground surface. The Eberline SPA-3 probes attached to the LAGS carts are described as being mounted at a height of approximately 15 cm above the ground. When using hand-held gamma radiation detection equipment the probe was positioned 1 m above the ground."

The height of the detectors for the gamma radiation survey systems ranged from 15 cm to 100 cm above the ground. The purpose of the surveys were to document gamma radiation levels over large infinite plane surfaces so the differences between the heights of the detectors was not a significant factor. Although the SPA-3 probes on the LAGS carts were originally mounted at the 15 cm height for the detection of small discrete sources of radioactivity in the Malvern Community of Scarborough, Ontario, the LAGS system works very well for the documentation of outdoor gamma radiation levels over large areas.

The E-PERM detectors deployed for outdoor radon measurements were installed at a height of 100 to 150 cm above the ground to sample outdoor air within the range of the typical breathing zone. The E-PERMS installed to measure background gamma radiation levels had to been installed at the same height as the radon monitors. The gamma data collected from these E-PERM installations were only used for the calculation of ambient radon and were not used in the prediction of outdoor gamma radiation exposure rates.

9. "Does the variation in probe height used in the various gamma radiation detection methods have an impact on the accuracy or precision of measurements? Is there any appreciable variation in the accuracy or precision of measurements that is inherent in LAGS, RGPSGS or hand-held gamma survey systems."

The height of the gamma radiation detector above the ground impacts on the efficiency of locating and characterizing small areas (less than a few square metres in area) with distinctive gamma radiation levels. For the surveys conducted on the residential properties in Deloro the LAGS system was used

to provide coverage of approximately 2 readings per square metre. This level of coverage is more than adequate for this type of application.

The larger scintillation crystals in the LAGS and RGPSGS system make these systems more sensitive to minor variations in background gamma radiation. The accuracy of the instruments is a function of their individual calibrations, which were performed by the Low-Level Radioactive Waste Management Office using their Ra-226 sources. All units used in the program were operating within the acceptable limits set by the LLRWMO.

10. "A footnote should be provided for Table 3.1 that identifies health-based criterion for gamma radiation."

The author believes that Table 3.1 is not the correct place to introduce a footnote pertaining to the FGTF criterion for gamma radiation. The criterion is more appropriately introduced and discussed in Section 4.

11. "In section 4.1, it is concluded that "13 residences and the Deloro Pumphouse have or may be close to having radon and corresponding radon daughter concentrations in excess of the April 1977 Federal Provincial Task Force criterion for radon".

A memorandum from SENES Consultants Limited, dated December 14, 1998, indicates that: "The results of the living area assessments for each of the 14 structures identified in the 11 November 1998 memo were reviewed. Based upon this review, 3 homes and the Pumphouse were removed from the list because the areas within the 3 homes having or close to having radon and corresponding radon daughter levels in excess of the 1977 criterion were not considered to be living areas."

The conclusions stated in the report should be consistent with the information relayed in the memorandum dated December 14, 1998.

The text of the final report was revised to be consistent with the December 14, 1998 memorandum. Three homes were removed from the list because the elevated radon levels were found within non-living areas of the homes (e.g. crawl space of basesment); however, the living areas of the remaining 10 residences were found to have or may be close to having radon and corresponding radon progeny concentrations higher than the April 1977 Federal Provincial Task Force criterion for radon of approximately 150 Bq/m^3, corresponding to a radon progeny level of 0.02 Working Levels.

APPENDIX F

INVENTORY OF RAW FIELD DATA FILES (CD-ROM FORMAT)